ARMY RESEARCH LABORATORY

Volume II: Compendium of Abstracts

by ARL Summer Student Research Symposium

ARL-TM-2010a **August 2010**

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14. ABSTRACT

The ARL Summer Student Research Symposium is an ARL Director's Award Program for all the students participating in various summer scholarship and contract activities across ARL. The goal of the program is to recognize and publicize exceptional achievements made by the students and their mentors in the support of Army science.

All college undergraduate and graduate students receiving research appointments and conducting summer studies at ARL are automatically enrolled in the symposium program. As an integral part of their summer study, all students are required to write a paper on their work which summarizes their major activity and its end product.

The program is conducted on two separate competitive levels: undergraduate and graduate. The format of the paper in both levels is the same. However, the evaluation will take into consideration the difference in the academic level of the students.

All students submitted their research paper for directorate review. Directorate judging panels selected two papers from each competition category for the laboratory-wide competition at the Summer Student Symposium on 10 August 2010.

Students selected by their directorate for competition participated in the one-day Summer Student Symposium on 10 August 2010. At the symposium the students presented their papers to the ARL Director and an ARL Fellows panel.

This volume of the Summer Student Symposium Proceedings contains the abstracts for all papers prepared for the Summer Student Symposium Program.

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Director's Foreword

The U.S. Army Research Laboratory (ARL) mission is to "Provide innovative science, technology, and analyses to enable full spectrum operations." As the Army's corporate laboratory, we provide the technological underpinnings critical to providing capabilities required by our current and future Soldiers.

Our nation is projected to experience a shortage of scientists and engineers. ARL recognizes the criticality of intellectual capital in generating capabilities for the Army. As the Army's corporate laboratory, addressing the projected shortfall is a key responsibility for us. We have, therefore, identified the nation's next generation of scientists and engineers as a key community of interest and have generated a robust educational outreach program to strengthen and support them. We have achieved many successes with this community. We believe that the breadth and depth of our outreach programs will have a significant positive effect on the participants, facilitating their journey toward becoming this Nation's next generation of scientists and engineers.

A fundamental component of our outreach program is to provide students research experiences at ARL. During the summer of 2010, we supported research experiences at ARL for over 150 undergraduate and graduate students. Each of these students writes a paper describing the results of the work they performed while at ARL. All of the papers were of high quality, but only a few could be presented at our student symposium. The abstracts for all papers prepared this summer are contained in this volume of the proceedings and they indicate that there were many excellent research projects with outstanding results. It is unfortunate that there was not enough time for us to have all of the papers presented. We would have enjoyed hearing them all.

We are very pleased to have hosted this outstanding group of students for the summer. It is our hope that they will continue their pursuit of technical degrees and will someday assist us in providing critical technologies for our Soldiers.

Introduction

The ARL Summer Student Research Symposium is an ARL Director's Award Program for all the students participating in various summer scholarship and contract activities across ARL. The goal of the program is to recognize and publicize exceptional achievements made by the students and their mentors in the support of Army science.

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This volume of the Summer Student Symposium Proceedings contains the abstracts for all papers prepared for the Summer Student Symposium Program.

A Study on Interactions of Catalysts with Quaternary Alkyl Ammonium Cations

Abbott, Daniel

Fuel cell technology offers a great versatility where a high energy density is required for extended mission duration. The alkaline anion exchange membrane (AAEM) fuel cell, which displays good kinetics and uses non-noble catalysts, is a promising alternative to proton exchange membranes (PEMs) and methanol fuel, which use expensive noble metal catalysts and have slow electrode kinetics. In order to design a better polymer electrolyte and catalyst for anion exchange membrane fuel cell (AEFC) electrodes, we must understand the interactions between the fixed charges at the termini of polymer side chains in the polymer electrolyte and the catalyst surface, and how such interactions affect the electrocatalytical activity of the catalysts by surface adsorption and surface coverage To simulate these interactions, I examined the effects of various quaternary alkyl ammonium cations on the surfaces properties (hydrogen adsorption/desorption) and electrochemical catalytic activities of Pt/C, PtRu/C, and transition metal macrocycle catalysts for methanol oxidation and oxygen reduction reactions using rotating electrode voltammetry. By changing the chemical nature of the alky group (from hydrocarbon to fluorocarbon, from phenyl to polar chain to reach a higher degree of hydration), the adsorption the alky groups on the catalyst surface and their impact on the catalyst activity could be easily verified. This knowledge could be useful for designing better alkaline membrane and ionomer materials to advance AEFC technology.

I wish to acknowledge the mentorship of Deryn Chu.

Real-Time Power-Line Simulator

Adelman, Ross

A real-time power-line simulator was developed using C# (for the graphical user interface) and MATLAB (for the numerical processing). This Windows application is capable of simulating and, optionally, transmitting continuous power-line field data over Ethernet and/or analog (stereo headset output). To begin the simulation, the user loads an animated scene of a house. The user then interactively turns on and off various loads in the scene, such as lights and fans. As this happens, various MATLAB plots show the voltages and currents of the lines feeding the house at the load locations. In addition, using a series of electric- and magnetic-field basis models, the simulator calculates the electric and magnetic fields nearby, and plots them. Optionally, the user may choose to have the data transmitted to another machine for real-time analysis. There are two methods for transmission. The data can be converted into an audio signal and transmitted through a stereo audio cable to the other machine. Alternatively, the data can be sent over the network using TCP/IP protocols. Only two channels of data can be sent using the former method, whereas any number of channels can be sent using the latter.

I wish to acknowledge the mentorship of Dave Hull.

High-Voltage Lithium-ion Batteries Composed of Sulfone-based Electrolytes Effectively Stabilized by Lithium Difluoro(Oxalate)Borate Additive

Allen, Joshua L.

Commercial lithium (Li)-ion battery electrolytes consist of mixed carbonate solvents and lithium hexafluorophosphate ($LiPF_6$). In recent years, there has been a strong interest in alternative lithium salts such as lithium bis(oxalate)borate and the hybrid of this salt with $LiBF_4$—lithium difluoro(oxalate)borate (LiDFOB)—either as a replacement for $LiPF_6$ or as additives. The use of carbonate solvents in Li-ion batteries limits the operating voltage due primarily to the electrochemical stability of the carbonate solvents themselves (~4.2 V). Recent attention has focused on replacing these carbonate-based solvents with sulfone-based solvents, which display a much larger stability window (>5 V); however, sulfone-based solvents themselves do not form a stable solid/electrolyte interface (SEI), which is crucial to the battery's performance. In order to form an effective SEI on both positive and negative electrodes, we incorporated small amounts of LiDFOB (2wt.%) into ethylmethylsulfone- and tetramethylenesulfone-based electrolytes, some of which contain carbonates (ethylene carbonate [EC], dimethyl carbonate [DMC], ethyl methyl carbonate [EMC]). Coin-cell cycling showed considerable difference in the cycling performance of each electrolyte with and without the additive (LiDFOB). We concluded that adding only a small amount of LiDFOB into sulfone-based electrolytes can significantly improve the capacity of the half-cells while cycling to 5 V.

I wish to acknowledge the mentorship of Drs. Richard Jow, Kang Xu, and Arthur Cresce for their invaluable guidance.

Optimizing Scintillator Shape for Maximum Radiation Collection

Argue, Robert

The ability of a scintillator to collect and focus light to a photomultiplier tube (PMT) is based on both its ability to convert radiation into optical photons, which is defined by its cross-sectional area, as well as its ability to retain these optical photons and transmit them to a PMT, which is based on its internal geometry. Light retention was modeled for cylindrical- and cone-shaped geometries using Monte Carlo techniques. Comparisons of effective radiation gathering were made through a parametric study of cone/collector angle and by luminosity (number of optical photons/MeV gamma energy). An 8% increase in sensitivity is achieved for cylindrical discs when the cone angle is 30%. The model is now being extended to include rectangular geometries.

I wish to acknowledge the mentorship of Marc Litz.

Reaction of Certain Aluminum Based Intermetallic Forming Materials

Aydelotte, Brady B.

I studied the mechanics of impact initiation of reactions in nickel (Ni)-aluminum (Al) and tantalum (Ta)-Al powder compacts. Experimental data on the reactions is compared with scanning electron microscopy (SEM) of the failure surfaces of the materials. Differences in the microstructure at fine length scales suggest a possible explanation for the differences in the observed reaction behavior.

I wish to acknowledge the mentorship of Barrie Homan, Kevin McNesby, and Naresh Thadhani as well as Dr. Fengchun Jiang, Dr. Eric Herbold, and Ryan Anderson for performing the Hopkinson Bar experiments.

Cultural Sensemaking Modeled as a Knowledge Management Tool Within the Army

Bagley, Katherine G.

The face of the U.S. Army has transformed, as focus has shifted towards military operations other than war (MOOTW), peacekeeping, counter-insurgency (COIN), and stability and support operations (SASO). These missions stimulate an interest in understanding the officers' mental state while adapting to the operational environment. Sensemaking is defined as a motivated, continuous effort to understand connections in order to act effectively. Using battle command literature, sensemaking methodologies, and officer interviews, this project explores how the sensemaking concept can be developed into a knowledge management tool. Knowledge management promotes an integrated approach to identifying, sharing, and evaluating knowledge assets. The scope of this project analyzes the roles of two division officers (G3-operations and G9-civil affairs officers); sensemaking questionnaires are developed to elicit their information requirements in military applications. We seek to understand how officers synthesize kinetic (operational) and non-kinetic information while tracking inconsistencies and knowledge gaps within the social network. Scale development theory and methods will be applied to assess sensemaking in a battle command context. This work is advantageous because sensemaking supports shared understanding, which impacts the officers' ability to make timely decisions in critical situations as new command approaches emerge.

I wish to acknowledge the mentorship of Donald Headley.

Wideband Dual Patch Aperture Coupled Antenna

Bamba, Amid M.

Three wideband dual patch antennas were simulated and designed using high frequency structural simulator (HFSS). My effort verified the performance of the antennas through radiation pattern and gain measurements in the anechoic chamber. The wideband dual patch antennas are made up of two aperture-coupled patch antennas designed to achieve a bandwidth of 73% and 83% for a standing wave ratio of 1.5:1 and 2.0:1, respectively. The antenna panels are held by a wooden construct that maintains a constant separation between the antennas. The first antenna contains the two aperture stacked antennas fed through a slot. The second antenna also has two microstrip reflectors supported by fiberglass and the third features an electromagnetic interference (EMI) absorbent material held by fiberglass sheet, which is also used as a back lobe reflector. The selected material and microstrip reduce back radiation and help increase antenna directivity. Radiation patterns change with frequency so the radiation pattern of the back side of the antenna may vary depending on the frequency of interest. These wideband dual patch antennas are intended for ultra-wideband radar applications. Future work will provide field measurements, including the radiation patterns of the antennas in their two perpendicular principal planes and antenna gain.

I wish to acknowledge the mentorship of Youn Lee.

Thermal Analysis and Novel On-Chip Velocity Characterization of Energetic Porous Silicon with Sodium Perchlorate Oxidizer

Becker, Collin

When a solution of sodium perchlorate ($NaClO_4$) in methanol is drop-cast onto porous silicon (PS) and dried under nitrogen (N_2), an explosive reaction can be initiated by heat, friction, or electrical spark. Here, PS films up to 150 μm thick are fabricated on p-type Si wafers without the need for an external power supply by employing a galvanic corrosion reaction in an electrolyte of hydrofluoric acid, ethanol, and hydrogen peroxide. Bomb calorimetry reveals PS-$NaClO_4$ to be a fuel-rich energetic material with a heat of reaction of 27.3 $\pm$ 3.2 and 9.9 $\pm$ 1.8 kJ/g in either an oxygen (O_2) or N_2 atmosphere, respectively. Differential scanning calorimetry (DSC) demonstrates that the PS-$NaClO_4$ exothermic reaction at a heating rate of 10 °C/min initiates at 250 °C and liberates ~600 J/g, but at 100 °C/min the reaction initiates at 320 °C and releases ~5400 J/g. The reaction velocity is studied by pattering thin-film resistor wires across PS strips 3 mm wide and up to 75 mm in length. An oscilloscope monitors the wires during the energetic reaction, and the time to failure is used to determine the speed of the reaction. The results indicate that velocity is on average 2100 m/s, but can fluctuate hundreds of m/s along the length of the chip. I discuss the results as they apply to the PS-$NaClO_4$ reaction mechanism and possible improvements to the energetic material.

I wish to acknowledge the mentorship of Dr. Luke Currano.

The Network Device Checklist Automator

Bennett, Donald A

The Department of Defense (DoD) 8500 series mandates that all agencies implement the Security Technical Implementation Guides (STIGs) released by the Defense Information Systems Agency (DISA). The STIGs are important, as they help ensure that essential resources are always available by standardizing configuration standards. Agencies are required to perform regular checks on all their systems for compliance with these regulations. To make the validation process easier, the DoD allows the use of Security Readiness Review Scripts (SRRS), which will automatically perform many checks and focus the auditors attention to critical areas. The DoD has stated that network devices are the most critical, but to date there are no commonly available Government automation tools for network devices such as routers, firewalls, switches, and intrusion detection systems (IDSs). Without sufficient support, many of these devices are running with little or no checking. The Network Device Checklist Automator (NDCA) seeks to become the first SRRS for network devices and provide the groundwork for future development. Our goal is to create a framework and implement full support for a few devices to demonstrate proof of concept in hopes of transitioning the project to DISA and other DoD components.

I wish to acknowledge the mentorship of Allison Clark and Curtis Arnold, as well as the contributions of Aaron Hiltgen.

A Parametric Study of Tungsten Penetrators Fired into Steel Rolled Homogeneous Armor

Brainard, Jr., Philip J.

A series of numerical and graphical simulations were performed, based on the Johnson-Cook (JC) strength model of materials, in order to study the effect of penetrator (rod) density and length-to-diameter (L/D) ratio on penetration depth. Tungsten heavy alloy (WHA) and rolled homogeneous armor (RHA) were modeled with three different empirical JC fits and used as parameters in CTH and ALE3D testing. The JC fits were obtained from three previous works done by U.S. Army Research Laboratory (ARL) employees. Three L/D ratios were used: 5, 10 and 15. Each ratio had its own velocity range at which the simulations were run. The ratios were also simulated in each of the JC fits, and once for each density. Simulations of the same L/D ratio and fit were compared against each other for the two densities. Results were graphed as penetration over rod length.

I wish to acknowledge the mentorship of Stephen Schraml.

Structural Health Monitoring System for Today's Military Vehicles and Aircraft

Brown, Nagid A.

The U.S. Army currently uses all kinds of vehicles as its sources of transportation. The vehicles and aircraft usually do not meet their life expectancies. This is mostly due to operators being unaware of severely damaging stresses or strains acting on the vehicle or aircraft. The concept behind a Structural Health Monitoring system is the installation of several non-invasive transmitters/receivers along the hull of a vehicle or aircraft that will emit sound waves throughout the vessel and be reflected back to the transmitter or picked up by another transmitter or receiver. The time it takes for the sound wave to be picked up by the receiver will determine if there is any damage to the vehicle/aircraft. We conducted experiments that included the testing the lead zirconium titrate (PZT) substrate with pulse echoes to determine the speed of sound through PZT. This testing was done by adhering two plates on either end of the substrate and sending a pulse wave from the plate through the substrate. The time it takes the pulse to travel to and from the opposite plate, along the distance between the two plates, was used to determine the speed of sound through the PZT substrate.

I wish to acknowledge the mentorship of Ryan Toonen.

A New Design Approach for Mitigating the Internal Diffraction Effects of the Rotman Lens

Buchanan, Kristopher R

The beam-forming network (BFN) is a critical device used in radar and communication array systems that allows the antenna array to scan electronically. Due to its superior performance and wideband and wide scan angle characteristics, the Rotman lens is a popular BFN. Analysis of the Rotman lens using various numerical techniques from software packages including XFDTD, HFSS, and CST has yielded no true optimization. In this paper, I explore a unique approach to optimizing the Rotman lens. I used FEKO code to simulate the Rotman lens with rounded and unrounded edges. Rounded edges are preferred since tapered contours are often closely spaced, and lead to points that adjacently touch on the contour, often at an obtuse angle that approaches 330° or more, thus introducing diffraction effects. These unwanted effects can be mitigated by rounding the edges in the initial design. I compare the simulated and measured data of two identical Rotman lenses (differing only by rounded edges). The analysis of the effects of rounding should prove beneficial in producing lower losses in the Rotman lens.

I wish to acknowledge the mentorship of Dr. Steven Weiss and Dr. Amir Zaghloul.

A Systematic Study of the Factors Influencing Coriolis Force Sensitivity on a Biomimetic Haltere

Bueno, Jonathan; Jordan, Kesshi

Millimeter- to centimeter-scale micro-air vehicles (MAV) require lightweight, low-power flight stabilization systems, but current microelectromechanical systems (MEMS) gyroscopes are too large and power hungry for this application. Comparably sized biological platforms (e.g., the housefly) use oscillating club-like structures called halteres to measure the Coriolis force from angular acceleration and stabilize flight. Biomimetic halteres have been fabricated, but little systematic experimentation has explored the relevant parameters for optimizing haltere systems. This research investigates the relationship between haltere geometry, tip velocity, and deformation response to an applied normal force. Theromplastic halteres of varying geometries are fabricated, piezoelectrically oscillated, and subjected to a localized laminar airstream to produce an impulse force normal to the plane of motion. This simulated Coriolis force is measured as a function of these control variables using a strain gauge at the base of the haltere. The experimentally correlated data are used to generate a one-dimensional control equation relating force and measured strain. Future research will extend the control equation to encompass three-dimensional motion, representing the impulse a system would experience on an angularly accelerating platform. This research establishes the parameter space to further optimize haltere design, complimenting current U.S. Army Research Laboratory (ARL) piezoelectric flapping wing research.

We wish to acknowledge the mentorship of Dr. William Nothwang and Dr. Alma Wickenden.

Alternative Solvents for Thinning and CARC Coatings

Burlin, Jacob D.

We conducted tests to examine the difference in solvents used for primers and topcoats. The goal of the project is to analyze more environmentally friendly solvents and compare their performances compared to the current standard. The standard solvent used in the testing is MIL-T-81772. The various parts of the testing include drying properties, methylethyl ketone (MEK) resistance, stability, and cleaning. Some of the tests that will be conducted include adhesion, cyclic corrosion, rusting, and the consistency of the paints. While it is still early in the testing, there have been some qualitative results on the primers. The 0 VOC solvents have comparable spraying ability, MEK resistance, drying properties, and stability. Using the new solvents as cleaners has proven to be comparable and, in some instances, easier than the current standard.

I wish to acknowledge the mentorship of Daniel Pope.

Implantation and Diffusion of Nitrogen in CdTe Photovoltaics

Bushnell, Reuben E.

The development of efficient and reliable alternative energy sources has become an issue of critical importance over the last two decades. One of the most promising materials for inorganic solar cells is cadmium telluride (CdTe), as its bandgap is well aligned with the solar spectrum. Despite this potential, the demonstrated efficiency of CdTe photovoltaics has not increased since 2001, and has fallen far behind cells made from silicon and III-V compounds. This is attributed to the large work function of p-doped CdTe, which makes it difficult to create the low-resistance ohmic contacts necessary for efficient electrodes. A method to alleviate this problem involves doping the p-type material with a Group V element so as to create a p+ region near the surface, which will be more amenable to contacting an electrode. Further study will involve x-ray photoelectron spectroscopy to study the distribution of nitrogen after implantation and also to investigate the effect of various post-processing techniques on nitrogen diffusion through the crystal.

I wish to acknowledge the mentorship of Dr. James Snyder and additional support from Dr. J. Derek Demaree, Dr. Thomas Parker, and Dr. James Hirvonen.

Feasibility of Quadrotor Obstacle and Collision Avoidance

Byrne, Brendan C.

In this paper, two path planning algorithms are investigated for their possible usage in multi-quadrotor systems. The two algorithms being evaluated are a velocity controller-based obstacle and collision avoidance system, and an elastic multi-particle system to generate a collision-free trajectory. Each algorithm will have the basis of its theoretical framework explained and then the results from the performed experiments will be shown. These experiments are constructed to showcase problems that the different algorithms may have. With the problems highlighted, one of the two algorithms is chosen as a possible candidate for implementation into the full-scale quadrotor system.

I wish to acknowledge the mentorship of Ethan Stump.

Redesign and Development of the Automotive Radio Adapter System

Callaway, Steven P.; Hopkins, Robert J.

The Automotive Radio Adapter system offers a single radio system containing power conditioning, battery backup, and radio frequency amplification, and allows for rapid removal of the radio by using a modular system with power and radio boxes. After a prototype was created, testing was completed. Following testing, the customer specified the need for a reduction in system size. This necessitated the redesign of several key components. A new battery, new power supply design, different housing access design, and a more affirmative radio latching mechanism were used. The new battery is smaller, but not removable from the system because it is hardwired into the circuits. The new power supply design reduces the number of connectors, but reduces serviceability by being mounted to the box top and tethered to the system. The housing redesign allows for a reduction in system height and reduces the part count, but it limits serviceability. The radio latch changes increase latch size while creating a stronger latch force. These tradeoffs sacrificed engineering features while satisfying new customer requirements, ultimately fulfilling the needs of the user. Overall, serviceability was sacrificed to reduce system size and increase general usability.

We wish to acknowledge the mentorship of Tim Rose.

Designing an Intuitive Interface with Master-Slave Control for Hyper Redundant Manipulators

Cannon, Daniel J.

Dexterous robotic manipulators that rely on joystick type interfaces for teleoperation require considerable time and effort to master and lack an intuitive basis for human-robot interaction. This hampers operator performance, increases cognitive workload, and limits overall effectiveness on highly dexterous tasks. A recent study demonstrated the intuitiveness of a replica interface and offered proof of concept to design a fully manipulatable replica interface capable of working with a variety of hyper redundant systems with Master-Slave feedback controls to improve teleoperation on dexterous tasks. Preliminary results from a Vicon simulation showed a replica interface can achieve a requisite range of motion and demonstrated how the system reacts in a controlled environment when blocked by an obstacle, sending configuration information unilaterally from the interface to the robot. Follow-up research will evaluate operator performance, human-robot interactions, and feedback control schemes on a replica interface for hyper redundant manipulators against the traditional joystick style interfaces. The research methodology will concentrate on finding feedback control schemes focused on reducing or eliminating common issues associated with Master-Slave controllers, such as latency, error, and robustness, while providing the operator with haptic feedback and visual cues.

I wish to acknowledge the mentorship of Mel Siegel, Harris Edge, and Howie Choset.

Determining a Statistical Model for Type 706 Kevlar with 4” Diameter Boundary

Chen, Albert J.

Kevlar is routinely used for light-weight armor solutions around the world. However, the statistical variation of its mechanical and physical properties has not been given sufficient attention. Ballistic and dynamic characterization of Kevlar is necessary to generate useful data for a successful armor design. One of the most common ways to evaluate armor material is by finding V50. V50 is defined as the velocity at which 50% of the impacts by a projectile penetrate a target under given conditions, such as target thickness. To carry out the study of the statistical variation of the Kevlar properties, 5.56-mm spherical projectiles, fired by a helium powered air gun, were shot at 100-mm (4 in) diameter sheets of Type 706 Kevlar (K706) of 0.23-mm nominal thickness. The generated data were introduced to Mott and Gumbel distribution models. Subsequent analysis showed that both models reproduced the experimental data with a good level of accuracy.

I wish to acknowledge the mentorship of Constantine Fountzoulas.

Effects of Target Area Constraints on the V_{50} Ballistic Limit

Chen, Richard

In this study, Type 706 Kevlar and Spectra Shield II SR-3124 were put through projectile penetration tests to study the effects of velocity and target area size on the probability of penetration of a 5.56-mm ball bearing. The planned target sizes to be tested included a 2-in-diameter circle and an unrestricted 6 x 6 in square for both Kevlar and Spectra samples. Targets were fired on using a gas powered gun. Data collection is still ongoing. Current data of the study were plotted, and respective V50 and C/γ values were calculated for the Kevlar only. The constants C and γ are unique to the material and target size, but lack of data has not allowed for determination of these constants. The data was then plotted against a Stochastic Failure Model curve, which modeled the probability of penetration of the Kevlar versus the velocity of the projectile.

I wish to acknowledge the mentorship of Dr. Chian-Fong Yen and Jian Yu.

$Pt/TiO_2/Ti$ Metal-Insulator-Metal Tunnel Diodes for Rectification in an Energy Harvesting System

Chin, Matthew L.

Methods for extracting or harvesting energy from the surrounding battlefield environment are of great importance to the U.S. Army. Scavenging energy from local environments reduces the required energy and weight transported to the theater. Micro/nanoscale metal-insulator-metal (MIM) tunnel diodes are being developed to provide electrical rectification as part of a "rectenna" energy harvesting system, which includes a radiation-collecting antenna, a rectifying MIM tunnel diode, and a storage capacitor. High-frequency MIM tunnel diodes were designed, fabricated, and characterized; planar $Pt/TiO_2/Ti$ stacks are being fabricated to create a diode with highly asymmetric current-voltage (I-V) characteristics that have a very low threshold voltage. I-V measurements were taken using an electrical characterization system to confirm a non-linear, asymmetric response on a survey of devices fabricated with varying areas. Preliminary results exhibit asymmetric I-V characteristics with threshold voltages of less than 700 mV. Alternative fabrication processes are being investigated to improve device yield, quality, and performance.

I wish to acknowledge the mentorship of Dr. Madan Dubey and Dr. Barbara Nichols.

Effect of Low-Energy Electron Irradiation Single-Walled Carbon Nanotube Bundles

Choi, Daniel S.

Single-walled carbon nanotubes (SWNTs) exhibit a number of desirable properties—such as semiconducting and metallic properties, excellent thermal conductivity, and a very high mechanical strength—that make them useful for nanoscale electronics applications. Recent experiments have shown that exposing SWNT bundles results in reversible debundling of the tubes, accompanied by a decrease/recovery of electrical conductivity. This research focuses on the effect of low-energy radiation exposure on SWNT wires switches. The devices were fabricated with chemical vapor deposited (CVD) SWNT on silicon (Si)/silicon oxide ($SiO_{2)}$ substrate and metalized with gold (Au) electrodes. Electrical measurements were performed with a four-probe electrometer using a Keithley SCS 4600 system. The devices were also analyzed with scanning electron microscopy (SEM). Our experiments show that under biased condition, the SWNT not only debundle, but also break when irradiated by a low-energy electron source of SEM. Further analysis and experiments to understand the underlying mechanisms are in progress.

I wish to acknowledge the mentorship of Shashi P. Karna. I thank Mr. Gary Hirsch and Dr. Govind Mallick for help with the experiments. I would also like to thank the Oak Ridge Institution of Science Education (ORISE) for the summer internship.

TopoDefUI – A Redesigned Graphical User Interface for the ARL TopoDef Tool

Christensen, Michael C.

TopoDefUI was designed and developed to be a more efficient and user-friendly method of inputting new model data into the existing tool, Topodef. In order to accomplish this, a new path-centric means of directing nodes was implemented, allowing researchers to quickly input the desired travel pattern for the node without having to manually reposition it every time step. In addition to the current graphical user interface (GUI), the underlying model-view-controller design pattern allows for new compatible interfaces to be developed with a minimum of restructuring or repetitious coding efforts.

I wish to acknowledge the guidance, patience, and goodwill of mentor Andrew Toth.

Isolation and Quantification of DNA from Apiezon Type L Grease

Clark, Alison M.

A protocol for extracting bacterial cells that are impacted in drum air samplers was developed to determine the quantity of the bacteria that are present in our air and how it can affect humans. This protocol involves quantitative real-time polymerase chain reaction (PCR), which is an efficient and inexpensive method for quantifying DNA. By isolating the crude extracts, including the DNA, from the bacteria in the grease found in air samplers, the integrity of the DNA can be determined in addition to the affect that the grease has on the bacteria. After *Escherichia coli* had been suspended in the grease for two weeks, there appeared to be no significant degradation of the DNA based upon the quantitative real-time PCR results. Further research needs to be done to determine the long-term effects of the grease on the *E. coli* and ensure that the quantitative real-time PCR protocol is the most efficient method for quantifying the bacteria.

I wish to acknowledge the mentorship of Christian Sund.

VMWare: Separate and Secure Evaluation of the BA-8180/U Battery for Unattended Ground Sensors Applications

Collins, Evan, L.

The performance of the BA-8180/U non-rechargeable zinc-air battery was evaluated for application in unattended ground sensors (UGS) and, more specifically, the OmniSense system. OmniSense is a Measurement and Signature Intelligence UGS system used for the autonomous detection and classification of personnel and vehicles in perimeter defense applications. The BA-8180/U battery was evaluated due to its high specific energy. The performance of BA8180/U batteries was evaluated under various temperatures, states of internal fan operation, continuous discharge, and intermittent discharge. The results show that the current design would not be optimal for use in UGSs. Under intermittent discharge (UGS simulation), the BA-8180/U performed poorly and lost over 50% of its specified capacity. It was possible to recover greater than 50% of the capacity under intermittent discharge by modifying the battery to disable the fan.

I wish to acknowledge the mentorship of Dr. Jeffrey Read.

Synthesis and Characterization of ZnO Quantum Dots

Cook, Heather

Current attentions of quantum dots (QDs), particularly zinc oxide (ZnO) nanoparticles, demonstrate their applicability in a wide range of technical focuses. Best known for their abilities as semiconductors and light-emitters, ZnO QDs are used for several applications, such as chemical sensors, bio-imaging, and light-emitting diodes (LEDs), to name a few. In this work, ZnO QDs were synthesized and characterized according to size and shape. The impact of these variables on their application as dye sensitized solar cell substrates are being tested.

I wish to acknowledge the mentorship of Dr. Govind Mallick.

Erbium-doped Yttrium Sesquioxide and Scandium Sesquioxide as Potential Laser Gain Media

Cote, Kris

Erbium-doped scandium sesquioxide ($Er:Sc_2O_3$) and yttrium sesquioxide ($Er:Y_2O_3$) are being studied as potential laser gain media because of their high thermal conductivity and high transparency in eye-safer wavelengths. Experiments conducted to date include fluorescence lifetime and absorption spectroscopy. The lifetime data have been used to evaluate the quality of an $Er:Sc_2O_3$ sample provided by Advanced Photonic Crystals. The absorption data have been used to determine the emission cross section of $Er:Y_2O_3$ through reciprocity, which was used to determine the samples potential for use in a laser.

I wish to acknowledge the mentorship of Larry Merkle.

Feasibility of Three-dimensional (3-D) Visualization Techniques for Ultra-wideband (UWB) Synthetic Aperture Radar (SAR)

Coyle, Andrew R.

The ultra-wideband (UWB) synthetic aperture radar (SAR) employed by the U.S. Army Research Laboratory (ARL) has many applications including detecting buried targets and sensing through the wall. Using an appropriate visualization technique, the data produced by the radar can be viewed as three-dimensional (3-D) images, as seen in the medical field, particularly with computed axial tomography scans and *magnetic resonance images*. This project evaluates the feasibility of applying the visualization methods used for medical data to UWB SAR data. This research focuses on implementing ray casting in software to assess its suitability for rendering SAR data, and compares its processing speed and ease-of-implementation against data from an established software package We examined three such packages—Paraview, Voreen, and Vox—and Paraview proved to be most useful, given its interactive graphical interface that allows users to view imported data using contour plots and two-dimensional (2-D) cuts, remove data subsets by thresholding, and replace data points by glyphs. Volume rendering in Paraview appears to be an appropriate technique for 3-D visualization of SAR images because the program is intuitive and its code is open-source. The animation feature of Paraview was also explored for generating electromagnetic simulation data.

I wish to acknowledge the mentorship of Lam Nguyen.

HAP-free Adhesive Replacement for Federal Specification MMM-A-1617B

Cremers, J.C. Todd

The goal of the Sustainable Painting Operations for the Total Army (SPOTA) program is to severely reduce the amount of hazardous air pollutants (HAP) emissions produced in coatings operations, including adhesives and sealant application and removal. This report focuses on the Federal Specification Adhesive, Rubber Base, General Purpose MMM-A-1617B (MMM-A-1617B) and the HAP-free replacements. We performed a 180° peel tension test on nine rubber-based contact adhesives on a variety of substrates, with and without exposure to various chemicals. Three baseline contact adhesives containing HAPs qualified for MMM-A-1617B and produced by Clifton Adhesive, Inc., were tested. Clifton provided three experimental contact adhesives that did not contain any HAPs, and claimed that they still met the requirements for the specification. Three possible alternative contact adhesives that did not contain HAPs, made by 3M, were also tested. The Clifton, HAP-containing baseline contact adhesives did not meet the required specification, nor did the Clifton experimental, HAP-free contact adhesives. The alternative, HAP-free 3M products met and exceeded the minimum requirements for the specification.

I wish to acknowledge the mentorship of Faye R. Toulan and Dr. John La Scala.

Development of Multi-Body Dynamics Analysis Capability for Flapping Wing Systems

Cross, David M.

MBDyn is an open source software tool capable of multi-body dynamics analysis. The Vehicles Technology Directorate (VTD) of the U.S. Army Research Laboratory (ARL) views MBDyn as a potential computational research and design tool for numerous aerial vehicle platforms. The most common application of MBDyn is for rotor-blade analysis, a subject of great interest to VTD. However, MBDyn provides a very generic environment for creating models and conducting dynamic analysis, making it suitable for numerous applications. One such application, also of interest to VTD, is research concerning flapping wing micro-aerial vehicles (FWMAVs). These systems are driven by the most advanced technologies and have great potential to aid the operational warfighter. The primary objective of this research is to build a preliminary model of a flapping wing system in MBDyn and evaluate it as a potential tool for future use at VTD. The preliminary models of flapping wing systems presented in this report illustrate that MBDyn possesses analysis capabilities well-suited to meet many VTD needs.

I wish to acknowledge the mentorship of Rajneesh Singh. I would also like to thank Dr. Matthew Floros for continued technical support, as well as Asha Hall and Jaret Riddick for their willing and helpful collaboration.

Cell-based Sensor for Characterization of *Pseudomonas aeruginosa* Mutability: The Effect of Microcolony Formation

Dakos, Alex

Many injuries in modern warfare are deep or internal wounds that eventually become infected by bacteria. Bacteria in wounds often develop drug resistances, a complex process that is still not well understood. Understanding the mechanisms underlying the development of drug resistance is critical for Army's ability to protect Soldiers from developing chronic wounds and eventually losing their lives or body parts. There are limited methods for studying the processes taking place in wounds. The goal of this project is to design a cell-based sensor system for measuring bacterial mutability in three bacterial states: (1) planktonic cultures, (2) microcolonies, and (3) biofilms, where the biofilms represent the host bacteria in wounds and the microcolonies represent other resident bacterial species. Two cell-based sensors are developed. One of the sensors is designed by expressing a green fluorescence protein reporter for frameshift mutations in wild type *Pseudomonas aeruginosa.* The other sensor uses the same reporter expressed in a *P. aeruginosa* mutant lacking the production of quorum-sensing quinolones. A growth media is developed that allows for the induction of all three bacterial states in similar nutritional conditions. I use confocal microscopy to detect frameshift mutation events and determine the mutation frequency.

I wish to acknowledge the mentorship of Dr. Dontcho Jelev.

Multi-Modal Sensor Data Processing

Danna, Dominic H.

The U.S. Army Research Laboratory (ARL) has been investigating fusing quasi-static electric and magnetic field sensor data produced by specific events directly related to human activity. Specifically, electrical loads were applied to instrumented facility power systems at multiple field experiments. This has resulted in large quantities of raw electric and magnetic field data that needs to be processed and analyzed. To efficiently accomplish this processing, custom ARL-designed algorithms for use with MATLAB are used to create readable output to identify and characterize the event type. The first level processing creates time plots of the electric fields and magnetic fields as a function of time. Test events can be observed based on a higher (or lower) amplitude change from a background state. The data are subsequently passed through another algorithm that generates two-dimensional (2-D) field phasor plots that are proportional to the magnitude and phase of the magnetic field, relative to the electric field. With three-axis sensors used at the experiments, multiple plots are generated for the various combinations of sensor outputs. This unique visual representation of the load event provides event detection and characterization capabilities.

I wish to acknowledge the mentorship of Steve Vinci and David Hull.

Polyimide Coating of Magnetic Ribbons Using Electrophoresis

Denton, Phillip M.

Magnetic inductors and transformers are critical components in military power converters, where high voltages and power density are required. Under certain conditions, the voltage between the core laminations can exceed the breakdown voltage of conventionally used dielectrics, thereby increasing eddy currents and power loss. Therefore, high quality, thin coatings to isolate the core laminations are needed. Nanocrystalline iron-cobalt alloys can operate at the desired flux densities and temperatures if electrical isolation can be achieved. The purpose of this research is to develop and characterize high quality polyimide thin films to serve as coatings on these alloys for use in transformer or inductor cores. Electrophoretic deposition was selected because this process can achieve thin, uniform films accurate to the microscale. Our films have been deposited as fast as 0.5 μm/s. Using deposited copper electrodes, the dielectric strength was measured across the polyimide. We found a 10-μm film typically could withstand 400 V, with a few samples able to withstand up to 1.8 kV. This is substantial for applications in transformer and inductor windings, which must withstand at least 100 V. Future work includes improving the dielectric strength of the film and electrophoresis deposition parameters to create uniform films with robust, repeatable qualities.

I wish to acknowledge the mentorship of Lauren Boteler.

Chemical Vapor Deposition of Graphene on Copper Substrates

Doleyres, Yasmine R.

Graphene growth on a copper substrate is achieved through chemical vapor deposition (CVD). CVD of graphene involves flowing methane and hydrogen gases over a thin copper foil at 1000 °C under a pressure of 1.5 Torr. The goal of the work is to vary the flows of both hydrogen and methane to determine which parameters are best to produce the highest quality monolayer graphene. After growth and successful transfer of the graphene samples onto oxidized silicon substrates, the graphene is characterized using Raman spectroscopy and atomic force microscopy (AFM) to determine the number and quality of the layers. Key aspects of the Raman spectra include the characteristic graphene peaks (the D, G, and 2D peaks at ~1350, ~1580, and ~2700 cm^{-1}, respectively), the shape of the peaks, and the intensity ratio of the G and 2D peaks. Likewise, AFM is used to determine uniformity and roughness of the samples. Finally, field effect transistors (FETs), with monolayer graphene incorporated as the semiconducting material, will be fabricated using standard microelectronic processing techniques. Once fabricated, the FETs will be tested to determine the electrical properties of the devices.

I wish to acknowledge the mentorship of Barbara Nichols.

Li_2CO_3 Doping of Electron Transfer Layers for Improved OLED Performance

Douglas, Erica A.

Demand for transparent flexible displays has become increasingly imperative, especially for military applications where present glass displays do not meet the durability, low weight, and low power consumption requirements essential for Soldiers in the battlefield. To realize these important Army applications, the effects of doping tris-(8-hydroxyquinoline) aluminum (Alq3) with lithium carbonate (Li_2CO_3) to improve the electro-optical characteristics of organic light emitting diodes (OLEDs) have been investigated. Thermally evaporated Li_2CO_3 was codeposited with Alq3 in various wt.% in order to effectively dope the electron transporting organic semiconductor, reduce the operating voltage, and increase efficiency. Two test structures were studied, structure A Glass/ITO/NPB(600Å)/Alq3(200Å)/Alq3:Li_2CO_3(400Å)/Mg:Ag and structure B Glass/ITO/NPB(600Å)/Alq3:Li_2CO_3(600Å)/Mg:Ag. At a bias of 15 V, structure A exhibited the highest current density of 236 mA/cm^2 with 4% Li_2CO_3, 61 mA/cm^2 greater than the standard device without doping. Structure A also had the largest decrease in on voltage (at 20 mA/cm^2) of 1.7 V, or 25%, as compared to the undoped standard. Structure B with 2% Li_2CO_3 doping increased the maximum current density 45 mA/cm^2 and decreased V_{ON} by 1.2 V (18%). These results show that with minimal doping device characteristics can be significantly improved, providing the Army with the technology for a flexible display that consumes less power.

I wish to acknowledge the mentorship of Dr. Jianmin Shi and Dr. Eric Forsythe.

Helicase-Assisted Polymerase Chain Reaction (PCR)

Dupuis, Christopher

The increased mobility and agility of U.S. Army forces has enabled maneuver units to execute extended missions away from their main base; however, these missions leave Soldiers more vulnerable to biohazard exposure. Biotechnological advancements continue to bring forth new methods of biohazard detection with potentially life-saving consequences. One such method with the potential to become a personalized platform for biohazard detection is Helicase-assisted polymerase chain reaction (PCR), which mimics cellular DNA replication to allow for equipment-free detection of genomic DNA. The goal of this project is to evaluate this new approach for Army biohazard detection. To accomplish this, we developed a model system using the drug-resistant bacteria *Staphylococcus aureus* (MRSA) as an example of a biohazard species in a pool of common environmental bacteria such as *Staphylococcus saprophyticus* and *Pseudomonas aeruginosa*. We identified the drug resistant gene *mec*A of *S. aureus* as the target gene and designed a unique set of primers for it. We then assessed different means for generating fragments of genomic DNA including shearing, sonication, and endonuclease-assisted DNA cleavage as hybridization sites for the primers. Finally, we used the targeting specificity of endonucleases to design genomic DNA fragments with different lengths for testing the effect of Helicase processivity on the PCR reaction.

I wish to acknowledge the mentorship of Dr. Dontcho Jelev.

A Case Study of How Malicious Exploits Can Impact Various Computer Systems

Durcholz, Michael

As our societal dependence on technology and communication between devices increases, so does the threat of malicious users launching exploits to impact the operation of these systems. In this paper, I discuss the methodology of some of the threats plaguing computer systems that interact with the Internet Protocol (IP) layer and discuss some exploits currently available on the internet.

I wish to acknowledge the mentorship of Dan Landin.

Roll-Stable Projectile Flight Dynamics Analysis for Precision Munitions

Dykes, John W.

There is growing interest to move away from unguided munitions towards higher-precision, guided munitions. While these smart projectiles allow for increased probability of hitting a target and lower collateral damage, controller systems for these munitions are required to be small, rugged, yet affordable. Factors contributing to higher costs include complex guidance, navigation, and control (GNC) algorithms, onboard energetics (thrusters), and large battery power demands. One idea to potentially reduce these issues is the concept of naturally roll-stable V-tailed projectiles. Similar to paper airplanes, a roll-stable projectile would be capable of uprighting itself during flight, due to aerodynamic loading in a gravity environment. Implementation of this concept would provide numerous advantages to flight control systems, including reduced actuator burden, higher maneuverability, reduced sensor burden, and simplified GNC algorithms. The scope of this study is to gain insight into the flight mechanics of roll-stable projectiles. A flight dynamic model for asymmetric V-tailed projectiles was developed to replicate flight characteristics observed from initial testing. Next, parametric variation of V-tail geometric parameters was performed. Results from these studies indicate that naturally roll-stable projectiles can exist. Conclusions of this study are based on aerodynamic predictions and rigid 6-degree-of-freedom trajectory simulation.

I wish to acknowledge the mentorship of team leaders Dr. Frank Fresconi and Ilmars Celmins. I further acknowledge the support and technical assistance of Branch Chief Dr. Paul Weinacht and co-worker Luisa Fairfax of the U.S. Army Research Laboratory's Weapons and Materials Research Directorate, Aerodynamics Branch. Additionally, I would like to acknowledge the assistance received from advisor Dr. Mark Costello of Georgia Institute of Technology.

Design and Fundamentals of a Multimodal Tool for Detection of Mild Traumatic Brain Injury

Eidsmore, Ashley E.

Mild traumatic brain injury (mTBI), caused by blast or impact, is one of the most common combat wounds suffered in recent conflicts. An mTBI leads to persistent post-concussion symptoms and often remains undiagnosed. While the precise causes and outcomes of mTBI are not yet understood, there is a substantial effort focused on detecting mTBI-like symptoms using a wide range of modalities. During this work, fundamental concepts associated with a multimodal detection tool for mTBI are explored. This is a multidisciplinary effort divided into three distinct areas: (1) a study of fundamental medical concepts for mTBI detection, (2) a design of a field deployable multimodal mTBI detection device that leverages existing state-of-the-art hardware and software, and (3) a software and hardware integration development plan using object-oriented programming. For this initial investigation, an Apple iPhone provides enough technology to begin to show interesting emergent concepts and properties of a mobile mTBI detection device. A significant result of this effort is BrainAid, a mobile application that provides a framework to understand multimodal measurement techniques to detect mTBI, and that provides a method for incorporating various cognitive status assessments in one portable, lightweight device. Challenges, constraints, and exciting future directions are discussed.

I wish to acknowledge the assistance of the entire Computational Injury Biomechanics Laboratory, especially the mentorship of Reuben Kraft.

PiezoMEMS Microflight Wing Performance

Faruque, Imraan A.

Recent interest in microflight (~1-mg vehicles) has inspired research into small-scale insect flight force generation. A set of bio-mimetic wings has been fabricated in an integrated process that combines 2-μm wing geometry with thin-film lead zirconate titanate (PZT) actuators, an actuation technology well suited to flight applications at this scale. The present study investigates over 100 different wings of varying design to characterize yield and uses video microscopy to measure baseline kinematics parameters such as stroke amplitude, offset, and frequency. These kinematic parameters may be used in flight control and aerodynamic analysis. Closed form expressions derived from basic quasi-steady aerodynamics are applied to compare aerodynamic force production capabilities.

I wish to acknowledge the mentorship of Jeffrey S. Pulskamp and Gabriel Smith and the contributions from Dr. Ronald G. Polcawich.

Reverse Engineering and Code Development for a Hybrid Remote Activation Munition System Receiver

Flechsig, Thomas E.

The Ml7 Remote Activation Munition System Receiver was developed by the U.S. Army Research Laboratory several years ago. A new Hybrid Receiver is currently being developed. A sub-project was undertaken to reverse engineer the M17 microcontroller assembly code for use in the Hybrid Receiver. The objectives of this project were to extract portions of code and make minor changes for implementation into the new receiver. First, the program was outlined to gain an understanding of the current program functionality. Then, timing diagrams were prepared depicting the way a single bit is read into the system. Flow charts on reception of full transmission data were then prepared. Finally, portions of code that could be used in the new system were determined. Minor software modifications were made and comments were added. In addition to this sub-project, a wide range of smaller, secondary initiatives were undertaken. Component specifications, schematics, and printed circuit board layouts were reviewed based on part obsolescence. Parts lists were amended and state diagrams and mode of operation documents were prepared. IPC standards on moisture sensitivity levels and necessary component bake times were determined to address moisture absorption into non-hermetic integrated circuits.

I wish to acknowledge the mentorship of Andrew Ladas.

Fretting Fatigue Investigation of CH-47 Chinook Engine/Transmission Materials

Fudger, Sean J.

The objective of this research was to evaluate the performance of materials associated with CH-47 Chinook engine/transmission (E/T) gears, which experienced a fretting fatigue-based failure mechanism in service. Boeing was tasked by the U.S. Army Cargo Program Management Office (PM Cargo) and the U.S. Army Aviation and Missile Command (AMCOM) Safety, Airworthiness Authority and Combat Developer to undertake a risk reduction program in conjunction with the U.S. Army Research Laboratory (ARL). As part of the program, ARL developed a unique fretting fatigue machine to reproduce the failure mechanism observed on the materials within the E/T systems. ARL has produced S-N curves to compare and contrast the performance of various material couples, carburization levels, coatings, surface roughness, surface enhancing processes, and lubricants to further the evaluation as a possible solution to the issue at hand. To determine how the carburization process has affected the materials' fatigue strength, specimens were produced in three distinct carbide levels—low, medium, and a level that represents the currently fielded gear average (production). Fretting fatigue performance of the various material couples and the typical fractography observed are discussed.

I wish to acknowledge the mentorship of Scott Grendahl.

Computing Ballistic Threat Using a General-Purpose Graphics Processing Unit

Gael, Peter

This work described in this paper is an extension of the Ballistic Threat Field Calculation (BTFC) project, which uses ray casting to identify and range terrain visible to a spotter in a specified location. In the extension, improved data structures and algorithms are implemented to accelerate the computation in order to frame the problem as optimization of spotter placement for maximum visible terrain. Since solving such an optimization problem by genetic algorithms, for example, would require many iterations of the ray-casting computation with static terrain but variable ray origin, the improvements are aimed at decreasing the actual cost of ray casting while possibly increasing the setup cost for a scene. Terrain detail is organized into voxels stored in a kd-tree, a balanced, efficient spatial indexing method based on the recursive binary partitioning of space. The kd-tree is more expensive to create than the currently-implemented quadtree, but the cost is amortized over the process of ray casting. The ray casting is further accelerated algorithmically by tracing each ray incrementally through intersected voxels in the direction of the ray, rather than checking each voxel for intersection and then examining triangles from all intersected voxels. The ray-triangle intersection computation, one of the principal bottlenecks in ray casting, is improved by precomputing ray-independent data for each triangle and storing it in a new data structure.

I wish to acknowledge the mentorship of Dale Shires.

Using Rapid Electrochemical Assessment of Paint to Determine Time to Fail

Gettleman, Jacob F.

Rapid electrochemical assessment of paint (REAP) is a procedure that can be applied in place of traditional corrosion techniques to determine the time to failure of a product and give it a ranking based on how long it would then take to fail. This can be applied to everything from batteries to fish, or in this case, primer, specifically MIL-DTL-53022 Type II (Solvent borne epoxyprimer). REAP is determined by taking a 0-h electrochemical impedance spectroscopy (EIS) reading, followed by a 24 h period of cathodic disbonding. After the period of disbonding, another EIS reading is done to determine REAP. In this experiment, panels are being run through traditional salt fog and cyclical corrosion tests alongside REAP to determine whether REAP is an acceptable method of determining relative time to fail. The potential benefit is that REAP can offer results in a fraction of the time of tank corrosion testing.

I wish to acknowledge the mentorship of William Lum.

Distributed Computing with Hadoop

Gollsneider, William

Hadoop is a distributed file system and job scheduler that is linearly scalable, according to its developers. Hadoop divides data and a job between its slave nodes, which process their portion of the data. The slaves each return an answer to the master, which recombines them into a single solution. The purpose of this research was to validate the claim of linear scalability by testing both file size and the number of nodes used to process data, to demonstrate the usefulness of Hadoop. The results of this research show that Hadoop is, indeed, linearly scalable when a few nodes or large file sizes are used. However, it does not scale when many nodes are used, or when processing small amounts of data, because the startup processing requirement for Hadoop is large compared to the total time needed when many nodes analyze a small data set. If the developers' claims hold true for large numbers of nodes, then Hadoop is designed to scale to thousands of nodes and terabytes of data.

I wish to acknowledge the mentorship of Jesse Kovach.

Adhesive Selection for Damage Tolerant Bonded Composites

Gonzalez, Geraldo

The goal of this research is to optimize adhesive bond strength and impact durability of assembled composite structures. Novel hybridized composite materials for Army ground vehicle applications will require adhesive bonding for assembly to meet loading and ballistic damage tolerance requirements. In this research, composite structures containing stainless steel, three-dimensional (3-D) woven graphite, and traditional fiberglass reinforced laminates were impacted by striking the panels midway between the center and the center of each quadrant. Using Scanning Capacitance Microscopy and force data from the drop tower impact tester, the degradation of each panel was analyzed to provide differentiation between each adhesive configuration and a qualitative view of degradation. It is anticipated that the results will show that composite degradation is reduced when the adhesive properties are selected with considerations made to the stiffness ratios between the bonded composite substrates, which is a significant driver in the mode of failure. Therefore, considering the broad range of loading conditions experienced by Army ground vehicles, there should also be an equally broad selection range of adhesives to optimize structurally bonded configurations.

I wish to acknowledge the mentorship of Robert Jensen.

Optimizing the CoNiMnP Electrodeposition Process using Taguchi Design of Experiments

Grapes, Michael D.

Thin-film magnetic materials with out-of-plane anisotropy are important for microelectromechanical systems (MEMS) actuation or microscale self-assembly, or any application requiring force at some distance. Electrodeposited magnetic alloys are the most easily integrated option because they do not require high-temperature processing or exotic seed layers. However, electrodeposition processes can be inconsistent, and optimizing such processes is difficult because of the large number of factors typically involved: seed layer, bath chemistry, current density, temperature, etc. Such problems are well suited to the Taguchi experiment design method, which we use here to determine and optimize factors with the largest influence on residual stress and out-of-plane magnetic properties of CoNiMnP films. A new process recipe resulted, which yielded a maximum energy density of 5.3 kJ/m^3, a remanence of 220 mT, and a coercivity of 93 kA/m. These results provide an improved material for immediate application in magnetic MEMS and magnetically driven self-assembly, and guidance for future work optimizing CoNiMnP or other electroplated cobalt alloys.

I wish to acknowledge the mentorship of Eugene Zaker.

Titanate Ceramics as Electrolytes from Lithium/Air Batteries

Green, Matthew

Lithium (Li)-air batteries have the highest theoretical energy density of any other battery currently used (~5200 W/kg). Many obstacles remain until we can exploit the full energy potential that this technology allows. One of the most daunting problems facing the advancement of Li-air technology is the necessity of a solid electrolytic membrane that will allow fast Li ion transport, high mechanical strength, and excellent chemical stability. Presently, there has been much research into the use of lithium lanthanum titanate (LLTO) ceramics (stoichiometry $Li_{3x}La_{(2/3)-x}TiO_3$) as a possible candidate for these membranes. The ongoing research conducted throughout the U.S. Army Research Laboratory (ARL) at Adelphi Laboratory Center (ALC) and Aberdeen Proving Ground (APG) is presented in this paper, and focuses on the use and improvements of LLTO ceramics for Li-air battery technology. Processing, sintering, electrochemical (ionic conduction, reduction/oxidation potentials, electronic resistance), and thermodynamic properties of the LLTO system were investigated in hopes of improving the ionic conductivity and density of the ceramics.

I wish to acknowledge the mentorship of Gary Gilde and Dr. Jeff Wolfenstien.

Novel Methacrylate Resins from Biobased Renewable Sources

Greer, Sylvester

In recent years, the Department of Defense (DoD) has turned towards using composites for an increasing number of applications. Unfortunately, the manufacture of composites relies heavily on the use of petroleum-derived resins. This paper details the efforts to synthesize renewable, bio-based replacements for traditional petroleum-based vinyl ester resins. The proposed replacement monomers were designed as the product of carbohydrate-derived chemicals (derived from naturally occurring sugars) and vinyl ester bearing compounds. The synthetic methods employed are simple, inexpensive, and commercially viable. This paper focuses on the work done to successfully produce the aforementioned monomers in sufficient yield as to return a formulatable resin for the determination of thermo-mechanical properties.

I wish to acknowledge the mentorship of John La Scala.

Implementation, Analysis, and Improvement of VFH for Enhanced Doorway Navigation on Autonomous Robots

Gregory, Jason M.

Warfighters have benefitted greatly from the use of man-portable, autonomous robots because of their ability to complete life-threatening tasks, especially in the case of urban warfare. A critical obstacle when achieving autonomy on robotic platforms is maneuvering doorways and other constricted spaces. Without the ability to handle tight environments, a robot's ability to move is greatly limited. There has been much research in the field of obstacle detection and avoidance for autonomous robots, but few methods have achieved elegant doorway navigation while maintaining the current velocity. This paper examines two algorithms for superior obstacle detection and avoidance—the Vector Field Histogram (VFH) algorithm, as well as the improved VFH algorithm. The simulations conducted using raw data suggest that the VFH algorithm is able to detect obstacles and small gaps well. The results from these simulations also suggest that the VFH method determines the optimal path to a desired goal location. Most importantly, this research looks to enhance performance by making novel revisions to the VFH method in an attempt to develop a local planner that handles doorway navigation gracefully.

I wish to thank Ethan Stump for his knowledgeable guidance, patience, and support throughout this project.

Circuit Design for a 20 kHz-bandwidth Electric Field Sensor Based on the D-dot Principle

Gunnarsson, Jeffrey M.

The electric field (E-field) sensing team at the U.S. Army Research Laboratory has developed novel methods for both detecting and interpreting E-field activity. Applications include personnel detection, electrostatic fuzing, bullet detection, and power-line monitoring. As this area of research has advanced, it has become increasingly necessary to develop high-quality and high-bandwidth sensing hardware to facilitate the research. This paper details the design process for one particular E-field sensor, a 20 kHz-bandwidth sensor based on the “D-Dot” principle (a D-dot E-field sensor creates an ideal short-circuit in the E-field at a particular location). Changes in the E-field give rise to a displacement current in the sensor, whose output signal is the time-derivative of the E-field. The concept and theory behind the sensor itself are explored and from this, a framework for the sensor circuitry requirements is developed. The desired sensor performance and theoretical model are then compared to experimental measurements.

I wish to acknowledge the mentorship of Steve Vinci.

High-performance MEMS Ball Bearing Systems

Hanrahan, Brendan M.

This work studies the performance of microball bearings and expands upon the current understanding of microfabricated bearings through friction testing and wear analysis. A hybrid silicon/steel bearing was actuated under loads up to 200 mN and lifetimes >20 million revolutions, demonstrating a 4- and 20-fold increase over previous tribology studies of microfabricated bearings. The tested silicon microturbine tribology device uses 440C steel microballs (Ø=285µm) placed within deep-reactive ion-etched silicon races and etched turbine structures for actuation. Analysis of worn raceways suggests that wear depends on a silicon phase transformation and the adhesion of stainless steel ball material. New testing methodology and optimized bearing geometry allow for studies of a broader range of normal loads (5–100 mN) and reveals a *Load^(2/3)* relationship with friction torque. The *L^(2/3)* dependence can be related to Hertz's derived load dependence of contact area of a sphere contacting a flat plane, thus proportionalizing contact area to rolling contact friction in the microfabricated bearing. These results demonstrate a ball bearing-supported microelectromechanical system (MEMS) that can be used for future high-performance microscale rotary applications, specifically in the areas of sensing and power generation.

I wish to acknowledge the mentorship of C. Mike Waits.

Extracting Real-Time Data from Manufactured Inertial Measurement Units

Hartnett, Meghan E.

Inertial sensors, such as accelerometers and gyroscopes, are essential to gaining knowledge of a projectile's orientation, velocity, and position in flight. With the goal of optimal performance, low cost, and condensed electronics, inertial measurement units (IMUs) are being studied to be integrated into guided projectiles. This paper will explore the advantages of a manufactured IMU, Analog Devices' ADIS16364 that includes a tri-axis gyroscope and tri-axis accelerometer, as well as a technique for real-time data extraction using a serial peripheral interface (SPI).

I wish to acknowledge the mentorship of Dr. Mark Ilg and technical guidance from Michael Don.

Development of High-Density Metallic Glasses

Hartwig, Joshua R.

Currently, our military uses depleted uranium (DU) for kinetic energy penetrators. The effectiveness of DU is based on its high density and self-sharpening behavior, attributed to its tendency to undergo adiabatic shear deformation resulting in a deep tunnel when penetrating armor. However, use of DU results in environmental and biological issues. Similar properties have been demonstrated with a hafnium (Hf)-based bulk metallic glass alloy-tungsten (W) composite; unfortunately, the alloy density, 11g/cm^3, and the unit cost of Hf, rendered this option cost ineffective. My objective is to identify an alternate metallic glass composition that is more affordable. I will identify eutectic combinations of elements (i.e., a low melting point), with a density of about 14g/cm^3. Prior efforts have indicated that W with Hf, nickel (Ni), or iron (Fe) show some promise.

I wish to acknowledge the mentorship of Suveen Mathaudhu.

Integrating Piezoresistive Sensor Elements with a MEMS Localizing Microphone

Helms, Tristan P.

In an effort to develop viable sensors for millimeter- to centimeter-scale robotic platforms, the U.S. Army Research Laboratory (ARL) is investigating microelectromechanical system (MEMS) microphones inspired by the tympanal membranes of the parasitoid fly *Ormia ochracea* for sound localization. The microphone consists of a pair of silicon membranes and a stiff coupling beam that amplifies differences in time response. This research investigates piezoresistive deflection sensing elements to reduce the overall sensor and processor size, the number of fabrication steps, and the required power. Since piezoresistive sensing elements exhibit a change in resistivity with applied strain, as in the deflection of an acoustic membrane in response to sound, their integration with an acoustic MEMS microphone should eliminate the requirement for integrated optical fiber guides, external circuitry, and signal processing This research focuses on the design of the piezoresistors and the fabrication processes for integrating them into the microphone. Piezoresistive strain elements are arranged in a full Wheatstone bridge around each membrane, with each set requiring nominally 15 mW power at 3 V. Future plans include characterizing the change in resistance to microphone deflections, mounting the units on a robotic platform, and investigating their applicability for navigation compared to an optical localizing microphone.

I wish to acknowledge the mentorship of Dr. Luke Currano, Dr. Alma Wickenden, Brian Isaacson, and Danny Gee.

Network Device Checklist Automator: Master Rule Set and Checklists

Hiltgen, Aaron P.

All information systems within the Department of Defense (DoD) are recommended to comply with Security Technical Implementation Guides (STIGs) released by the Defense Information Systems Agency (DISA) to protect the systems against attackers and misuse. STIG compliance validation is typically automated through the use of Security Readiness Review Scripts (SRRS). The Network Device Checklist Automator (NDCA) is intended to serve as proof of concept that an SRRS can be implemented for network devices. The NDCA will hopefully be transitioned to other organizations for further evaluation and testing, and eventual implementation by all sections of the DoD tasked with ensuring network device STIG compliance. The NDCA is comprised of two parts. The first part is a graphical user interface (GUI) responsible for loading information, rule checks, and report generation; the second part is a master rule set and device checklists created from STIGs. My work focuses on the second part of the project—creation of the checklists and master rule set. The rule set uses a pattern matching structure known as Regular Expressions (Regex) to create patterns from the rules in a STIG, which are then used by the NDCA GUI to determine if a configuration file is in compliance with a STIG.

I wish to acknowledge the mentorship of Duncan Rose, Curtis Arnold, and Allison Clark, as well as the contributions of my fellow intern, Don Bennett.

Capillary Electrophoresis for a Binding Analysis of Peptide Molecular Recognition Element (MRE) Interactions with the Protective Antigen Protein from *B. Anthracis*

Hite, Austin J.

Since 2001, when terrorists attacked the U.S. Postal Service using Anthrax spores, U.S. scientists have been focused on creating a biosensor capable of detecting these lethal organisms. Research using the capillary electrophoresis instrument provides analytical data that allows researchers to prescreen samples for binding affinity and offers insight into rational binder development with deoxyribonucleic acid (DNA) or peptide aptamer libraries. This development provides a faster and cheaper strategy than prior methods of creating biosensors using monoclonal antibody technology (mAb). Successful completion of this project, which studies the binding of peptide molecular recognition element (MRE) interactions with the protective antigen protein from *Bacillus anthracis*, will result in the design of durable single-use biological and chemical warfare detection sensors called Hand-Held Assays (HHAs). With the help of the capillary electrophoresis instrument, scientists can determine and generate accurate data in order to understand protein binding and elucidate the electrophoretic charges within protein or DNA molecules.

I wish to acknowledge the mentorship of Dr. Joshua Kogot.

Abstract: Topology Optimization Based Lightweight Military Armor Development

Hofstetter, Jr., Dwight D.

Improvised explosive devices (IEDs) present a constant and continually changing threat to the vehicles on the modern battlefield. Continual reengineering is needed to keep up with these threats and to safeguard the vehicles and the warfighters. To achieve this, protection kits need to be added to the vehicles. However, armor kits are a concession between maximum strength and minimum weight. LS-OPT/Topology optimization software takes into account size, shape, and topology by designing for a uniform internal energy density in the structure, while keeping the mass constrained. The user needs to develop a model matching the allowable limits of the desired part with a finite element analysis preprocessor. Then, the model is imported into LS-OPT/Topology and specific design limits are set. The program makes constant iterations until a tolerance with respect to the design limit (in this case mass fraction) is reached, or the amount of iterations have surpassed the set boundary. This paper explores the practical usage of LS-OPT/Topology that can be used by the engineers at the U.S. Army Research Laboratory (ARL) to improve the modeling and simulation capabilities in the area of vehicle protection leading to greater Soldier survivability.

I wish to acknowledge the mentorship of Dr. Rahul Gupta.

Mechanical Characterization of S-2 Glass Reinforced Polymer Composites for Army Materials Database Population

Hollifield, James

In an effort to investigate the suitability of a wide range of composite materials for Army applications, a database has been created that houses the mechanical properties of many composite materials that use S-2 glass reinforcement and various thermoset and thermoplastic matrices. These composite materials' properties are gathered through various tests, which are then compared to the results of the legacy S-2/SC-15 system. The four types of tests that were carried out consisted of short beam shear, tensile, compression, and the Izod impact test. Through comparison it was evident that the other composite systems that were tested performed better than S-2/SC-15 in certain categories, but no single composite system was capable of excelling in all the categories tested. Further testing will include end notch flexure, drop tower impact, and compression after impact.

I wish to acknowledge the mentorship of Michael Maher.

Portable Ring-Resonator Permittivity Measurement System

Hu, Jie

Accurate measurements of the electromagnetic (EM) properties of soil and explosives are essential for valid radar environment modeling and successful target detection by radar sensors. One important EM property is permittivity, which indicates the reflectivity or absorption of an incident electric field by a material. Permittivity varies from material to material, depending on temperature, water content, location, and time-of-day. Accurate modeling requires measuring samples as near to the radar test as possible. Our proposed measurement system is inexpensive and portable. Our technique uses ring resonators to measure the change between resonant properties of a microstrip ring in the presence and absence of the dielectric sample to calculate the sample's permittivity. Commercial off-the-shelf components are used to excite the ring structure, measure its resonant properties, and calculate permittivity. The system uses a Microchip PIC18F14K50 as the microcontroller and a PicKit2 evaluation board to prototype the microchip. The function calls needed to tune a wideband voltage-controlled oscillator (VCO) and transfer power-vs.-frequency data to a laptop over a universal serial bus (USB) are extracted from Microchip's PIC18 documentation. The paper describe the preliminary C code written to test VCO control and USB communication, and Windows drivers and MATLAB scripts developed to interface the laptop with RF power sensors.

I wish to acknowledge the mentorship of Gregory Mazzaro.

Design of Biological/Synthetic Hybrid Material Approaches for Army Applications

Huang, Jamie K.

Integration of synthetic and biomaterials into novel hybrid systems has potential utility in a variety of Army applications. Chitosan is a biocompatible and biodegradable material that can be produced in large quantities. This project focuses on exploring alternative coupling methods and chemistries for chitosan functionalization. As a proof-of-principle, chitosan is being grafted with polyethylene glycol (PEG), polypropylene oxide (PPO), or dodecane to alter the pure chitosan wettability. Preliminary Fourier transform infrared spectroscopy (FTIR) results and contact angle measurements provide contradictory data regarding the degree of functionalization. This contradiction is currently being explored through repeated experimentation and may be due to the preferential segregation of low surface tension groups to the air interface during film casting. Angle-resolved x-ray photoelectron spectroscopy (XPS) and synchrotron near edge x-ray absorption fine structure (NEXAFS) will be explored to examine the surface chemistries.

I wish to acknowledge the mentorship of Joseph Lenhart and Randy Mrozek.

Emission and Excitation Study of Er^{3+} doped AlN ceramic

Hussey, Lindsay K.

High power lasers are useful to the U.S. Army as a defense against rockets, artillery, and mortars; however, even scattered light from such lasers can be damaging to the eyesight of Soldiers. In order to increase Soldier safety, it is imperative to develop lasers emitting at wavelengths safer to the human eye. Because erbium (Er^{3+}) ions emit at a wavelength that does not reach the human retina and due to the high thermal conductivity of aluminum nitride (AlN), ceramic Er^{3+}:AlN is a material of interest as gain media for high power, eye safer lasers. In this study, the optical transitions of ceramic Er^{3+}:AlN are investigated by emission and excitation spectroscopy. The information provided by the emission and excitation spectra reveals the influence of the ceramic AlN host medium on the emission properties of the Er^{3+} ions and determines the feasibility of ceramic Er^{3+}:AlN as a high power, eye safe laser medium.

I wish to acknowledge the mentorship of Larry Merkle.

Characterization of DNA Films for Bioelectronic Devices

Jacob, Christina M.

DNA has the ability to form precise, predictable nanostructures that are both sturdy and flexible. These tunable properties make DNA an ideal candidate for use in a variety of systems, including nano-scaffolds for metal deposition and dielectric layers for electronic devices. From carefully chosen sequences, two single strands of DNA can be reconstituted into a variety of sizes or shapes, whether in two or three dimensions. By making a DNA-surfactant complex, these higher order structures become insoluble in aqueous media and soluble in organic solvents, making them optimal for use in electronic devices. Data collected from these experiments demonstrate that not only can these DNA molecules form a complex with surfactants, but they also retain their original structure upon re-dissolving in various organic solvents. I determined that hexadecyltri-methylammonium chloride (CTAC), as a surfactant, created a visible complex, as well as a complex that was readily dissolved in 1-butanol. Additionally, experiments concluded that the method of spin-casting a sample onto a flat surface created a more uniform, smooth film of DNA.

I wish to acknowledge the mentorship of Dr. Amethist Finch and Dr. Christopher Anton.

Adaptive Multiresolution PSK and QAM Modulation for Multimedia Traffic in Fading Channel Environments

James, Justin O.

Future wireless communications devices will be required to support a multitude of services with different reliability requirements. However, achieving such flexible systems are challenging in Mobile Ad-hoc Networks (MANET) due to limited battery resources at mobile nodes, coupled with unfavorable propagation environments. Therefore, it is our supposition that adaptive signaling techniques can be designed to take advantage of the differences in the quality of service (QoS) requirements among different types of multimedia traffic. By employing these adaptive signaling techniques with Unequal Error Protection (UEP), we strive to improve the energy efficiency and increase the data rate (spectral efficiency) over a fading channel. In this study, we expanded upon previous research using exponential approximation to asymmetrical phase-shift key (PSK) and quadrature amplitude (QAM) modulations to create readily invertible expressions, which can be used for Adaptive Multiresolution Modulation (AMM). Using the exponential approximation, we generated the curve fitting approximations for the average packet error rate (PER) and individual PER probability for 4-PSK, 8-PSK, 16-PSK, 16-QAM, 64-QAM, and 256-QAM. In this paper, we demonstrate the efficacy of the exponential approximation for the aforementioned AMM scheme in terms of PER, which is unlike most previous studies which were based primarily on bit error rate (BER).

I wish to acknowledge the mentorship of Lisa Scott.

Cargo Unmanned Aerial System Trade Study

Johnson, Kevin, L.

This paper addresses one specific and extremely important capability gap: the inability to provide supplies to a group of trapped Soldiers. The goal of this study is to analyze the requirements and constraints imposed by the scenario by performing parametric trade studies. In order to fully understand the cargo supply shortfall, the current assets and cargo supply operations are discussed for varying types of ground, sea, and air platforms. Once a thorough understanding of the problem is developed, a methodology is presented that attempts to address the capability gap. The methodology provides the necessary steps to adequately develop requirements on the system and mission by directly determining the inhibitors of current assets and Concept of Operations (CONOPS) shortfalls. These requirements provide the necessary framework for constraining the design space to a feasible size such that unmanned baseline systems are realized. A parametric modeling and simulation environment is developed to perform synthesis and sizing, which provides the ability to produce a quantitative assessment of system performance. The methodology culminates into a parametric design and tradeoff environment, which enables trade studies to be performed in order to make important design and investment decisions regarding the cargo unmanned aerial system (UAS).

I wish to acknowledge the mentorship of Mr. Elias Rigas and Dr. Mark Nixon.

Data Association of Stochastic Feature Maps Using Nearest Neighbor Constraints

Jones, Brandon M.

One of the core problems in simultaneous location and mapping (SLAM) is data association. For multi-robot SLAM, data association is a two-fold problem in that (1) each individual robotic platform must correctly identify feature-measurement correspondences to facilitate the building of a local feature map, and (2) the platforms must eventually integrate their knowledge of the environment, in the form of feature maps, to construct a single stochastic map. The main challenge in the multi-robot case is that, in general, coordinate systems vary across the platforms from a global perspective—rendering techniques such as \emph{nearest neighbor (NN)}, \emph{maximum likelihood (ML)}, and \emph{joint compatibility branch and bound (JCBB)}, in their current form, inapplicable due to the global nature of this problem. Given a set of local stochastic feature maps, our objective is to find the correspondences between these maps to form a single monolithic feature map, which is a global data association problem.

I wish to acknowledge the mentorship of Ethan Stump.

Functional Gradient Materials via Photopolymerization and Controlled Filler Methodologies

June, Stephen M.

Gradient functional materials, which exhibit a change in properties through at least one axis of the bulk, have received attention in recent years for their potential in biological and biomimetic devices. Photo-initiated polymerization has proven useful for the synthesis of materials that exhibit gradient properties, but the literature lacks systematic synthetic, morphological, and mechanical studies of the properties of these materials. Discussed herein are the syntheses of several different polymeric systems that exhibit both chemical conversion and filler content gradients. The impact of these methodologies is explored with respect to chemical and morphological structure on the properties of these gradient systems. Once synthesized, the samples were characterized with atomic force microscopy (AFM), nanoindentation, optical microscopy, and Raman spectroscopy. Usage of isocyanate chemistry for further post-crosslinking may enhance the gradient properties. Furthermore, the order of operations (isocyanate curing, then ultraviolet [UV] curing, or vice versa) is found to have an effect on the gradient properties of these materials.

I wish to acknowledge the mentorship of Josh Orlicki.

Microelectromechanical System (MEMS) Switch Test

Karter, Stanley

Analyzing microelectromechanical system (MEMS) switch behavior is a new field of study, which guides the production of MEMS switches. I analyzed switch behavior using a digital circuit synthesized on a field-programmable gate array (FPGA) chip. The chip had two outputs and one input connected to a MEMS switch and a radio frequency (RF) generator. It opened and closed the switch repeatedly and measured the resistance across that switch. The circuit consisted of the switch, a resistor, and the voltage out signal. I calculated the switch resistance from the voltage output applied on one end of the switch and the voltage input that lies between the switch and the resistor. The second output was the bias voltage needed to close the switch. A DA/AD converter translated the digital signal from the chip to the analog signal interacting with the switch. Parameters, such as the bias voltage, were entered into the chip using a software application on a computer.

I wish to acknowledge the mentorship of Edward Viveiros.

Choosing a Forensic Characterization Method for Radio Frequency (RF) Devices

King-Smith, Deen N.E.

We present a general framework for forensic characterization of radio frequency (RF) devices. This framework applies to a broad range of devices with RF front-ends. When a device is excited by a specially designed RF probe signal, a portion of the probe energy is re-emitted and is known as the reflected response of the device. The reflected response contains features that are specific to components contained in the RF front-end. This paper describes the probe signal, device model, feature selection methods, and classifier design, and provides experimental results to verify our approach.

I wish to acknowledge the mentorship of Dr. Anthony Martone.

Aperiodic Rotman Lens

Kishk, Mohammad A

Rotman lens beamformers are wideband and tend to be more cost effective than competitor beamformers strategies such as those based on microelectromechanical system (MEMS) phase shifters. A novel aperiodic Rotman lens has been developed that can work in either periodic or aperiodic configurations—if designed correctly. Using High Frequency Structure Simulator (HFSS) for design and optimization, such a Rotman lens was fabricated for the purposes of comparison and accuracy of design. Using the aperiodic configuration to reduce the grating lobes over the periodic Rotman lens allows one to still retain the desirable aspect of having the phase controlled through the Rotman's time-delay features. As constructed, the aperiodic Rotman lens has 11 array ports and 8 beam ports with any additional (not used) ports being terminated with 50 ohm loads. This paper presents the measured and simulated data from this study.

I wish to acknowledge the mentorship of Dr. Amir Zaghloul and Dr. Steven Weiss.

Arabic OCR Evaluation in Order to Develop a Post-OCR Module

Kjersten, Brian H.

Optical character recognition (OCR) is the process of converting an image of a document into text. While progress in OCR research has enabled low error rates for English text in low-noise images, performance is still poor for noisy images and documents in other languages. We intend to create a post-OCR processing module for noisy Arabic documents, which can correct OCR errors before passing the resulting Arabic text to a translation system. To this end, we are evaluating an Arabic-script OCR engine on documents with the same content but varying levels of image quality. We have found that OCR text accuracy can be improved with different stages of pre-OCR image processing: (1) filtering out low-contrast images to avoid "hallucination" of characters, (2) removing marks from images with cleanup software to prevent their misrecognition, and (3) zoning multi-column images with segmentation software to enable recognition of all zones. The specific errors observed in OCR will form the basis of training data for our post-OCR correction module.

I wish to acknowledge the mentorship of Clare Voss.

Medium-sized ISR Unmanned Aircraft Study: Platform Selection, Conceptual Design, and Trade Studies

Kooiman, James, E.

Improving medium-sized intelligence, surveillance, and reconnaissance (ISR) unmanned aerial systems (UASs), from sizing and layout changes to technology integration, is the focus of this study, motivated by the increased demand for capable, flexible, and reliable ISR systems, as demonstrated by the increased funding and flight hours of such systems in current conflicts. The focus is on systems that satisfy the Group 3 UAS requirements as defined in the *U.S. Army Roadmap for UAS 2010-2035*, for example, the RQ-7B Shadow tactical UAS (TUAS). The first part of this study considers advanced concept selection while the second part deals with conceptual design and trade studies of two different platforms. In the first, qualitative trades are made between systems varying from conventional fixed wing aircraft to ducted fans. Using systems engineering techniques (i.e., analytic hierarchy process [AHP] and fuzzy technique for order performance by similarity to ideal solution [TOPSIS]) and comparing concepts in terms of mission flexibility, logistical footprint, performance, and cost, an advanced concept is selected. This concept and the current UAS are then conceptually designed and trades are performed to identify the critical characteristics and technologies with the largest impact on performance in order to draw conclusions for future project planning and technology investment.

Note: The current paper is incomplete; the problem has been formulated and the procedures identified, but the final results in the process of being generated.

I wish to acknowledge the mentorship of Mr. Elias Rigas and Dr. Mark Nixon.

Thermally Reduced Graphene Oxide Coated on Kevlar Fibers to Create Supercapacitor Electrodes

Krintz, Jacquelyn M.

Wearable electronics have become a growing topic of interest for the application of supercapacitors. Numerous studies have used graphene because of its mechanical and chemical stability in supercapacitors. By using a derivative of graphene—reduced graphene oxide (GO)—the capacitance can be greatly increased, therefore, potentially increasing a supercapacitor's energy density needed for sufficient energy storage. To further investigate this, Kevlar and carbon fibers were used as substrates to create three different electrodes: (1) Kevlar fibers with GO, (2) carbon fibers with GO, and (3) Kevlar fibers and carbon fibers with GO. The use of Kevlar and GO serves a dual purpose: providing ballistic protection while also being an energy storage device. It was noted that the addition of the carbon fibers greatly increased the capacitance; however, the Kevlar fibers did not seem to contribute to the capacitance, even with the presence of reduced GO. Furthermore, reduced GO improved the capacitance of the electrodes that contained carbon fiber by at least 30-fold.

I wish to acknowledge the mentorship of Dr. Matthew Ervin.

Visual Anatomical Injury Descriptor (AID)

Kulaga, Autumn R.

Visual Anatomical Injury Descriptor (Visual AID) is a graphical computer tool developed to illustrate injury and severity on an anatomic figure. This graphical tool allows users to communicate trauma by visualizing human injury with associated severity on a digital illustration. These illustrations have drastically improved the communication of data and analysis involving injury. Visual AID is useful to those performing analysis of injuries based on information from casualty medical records or simulated through modeling and simulation. It has been connected to the Abbreviated Injury Scale (AIS), an anatomical scoring system that ranks the severity of injury and provides a consistent technique for describing trauma. In order to allow for quick and efficient development of such a tool, five phases were planned. The first phase is complete and provides a user interface to build trauma illustrations by selecting specific anatomic structures and injury severities. Each illustration, including a list of the user's selections, is shown to the user in real-time as selections are made. Development of this tool will continue through July–September 2010 to complete the remaining phases.

I wish to acknowledge Ronald Weaver and Tim Myers for their technical insight and programming expertise on this project, Patrick Gillich for excellent mentorship, and Latrice Hall for speaking up during times when good advice was needed.

Evaluation of the Effects of Induction Time in Epoxy Primer Preparation

Lai, Justin T.

This report investigates the necessity of induction time, or the settling period for the reaction chemistry between the base and activator that affects an epoxy coating's curing properties, during the preparation of two-component epoxy primers. Two different epoxy coatings, a standard solvent-based formulation and a more recently developed water-reducible coating, were prepared under two differing schemes. After application to a steel panel substrate, these coatings were then evaluated based on their adhesive properties and solvent resistance, while any variations in preparation, application, and cleaning had already been documented. As further testing—specifically degree of rusting, salt spray (fog) corrosion, and cyclic corrosion—will require much more time to complete in order to provide significant discrepancies in coating performance, results will be updated at a later date.

I wish to acknowledge the mentorship of William Lum.

Processing Techniques for X-Linked Aerogels to Yield Large Mechanically Strong Samples

Larimore, Zachary

Aerogels have long been used strictly for their insulation properties due to their fragility and the inability to produce large samples of them. However, through the development of x-linking and new processing techniques, the feasibility of producing relatively large samples with increased mechanical properties has been realized. Issues in processing have historically involved the fragility and the inability to handle the native wet gel. Relatively large polyurea, vanadium oxide, templated silica, and acrylic aerogels were produced with the use of some or all of these techniques. The use of additives and improved mold design were used to eliminate the bulk of these issues. Additives were used to increase the overall strength of the wet gel while only slightly increasing the overall bulk density of the finished aerogel, while molds have been designed to eliminate the need for handling of the wet gel during processing.

I wish to acknowledge the mentorship of Larry Holmes and Jared Gardner.

Synthesis and Characterization of Gold-Silver Alloy Nanoparticles for Photovoltaic Applications

Lee, Eric

Metallic nanoparticles, such as gold (Au) and silver (Ag), exhibit interesting structural, optical, electronic, and photoelectric properties, which often vary with particle diameter. When synthesized as alloys, as compared to purely monometallic particles, changes in the synthesis procedure and conditions can yield nanoparticles with entirely different structural, electronic, and optical properties. The focus of this research is to synthesize and characterize structure and photovoltaic properties of Au-Ag alloy nanoparticles. We used solution-phase and replacement-reaction synthesis that led to both single element nanoparticles within the quantum range (<15 nm in diameter), and alloy nanoparticles of Au and Ag in aqueous solution. Through UV-V is spectroscopy and spectrofluoroscopy, the existence of an alloy metal was characterized through the presence of a single, combined absorbance and emission peak. Particle size analysis through dynamic light scattering, atomic force microscopy, and transmission electron microscopy all concluded that alloy nanoparticles synthesized through replacement reactions resulted in a uniform size distribution of particles. Photoelectric cells were created using a titanium dioxide substrate, and potential voltage and current were both collected.

I wish to acknowledge the mentorship of Shashi P. Karna.

Mechanical properties of Ultra-fine grained and Nanocrystalline Tantalum

Ligda, Jonathan P.

High pressure torsion (HPT) is a severe plastic deformation technique capable of refining metal grain size from the course grain regime down to the ultra-fine grain (UFG) and nanocrystalline (NC) regimes. Materials with grain sizes in these areas show dramatic changes in mechanical properties such as strength, toughness, strain rate sensitivity, and deformation mode. Tantalum, a body-centered cubic (bcc) refractory metal, is of interest because past reports from Wei et al. show that, when loaded in compression, UFG/NC-bcc metals can experience localized plastic flow, a change from the course grain behavior. We are able to fabricate tension and compression samples with dimensions between 1–10 μm using focused ion beam (FIB) milling. Compression tests are performed using a conventional nanoindenter technique reported by Uchic et al., where the normal pyramid shaped tip is replaced with a flat punch and stress calculated using load-displacement measurements. Samples are tested in tension with a custom built in-situ SEM stage capable of measuring load/stress using a data acquisition program, while the strain is calculated using the displacement between gauge markers measured by a MATLAB program. This work reports on the mechanical properties of UFG/NC Ta obtained through these compression and tension tests.

I wish to acknowledge the mentorship of Dr. Brian E. Schuster.

The Effect of Hair Density on Head Tactile Sensitivity

Lowery, Janea

An experiment will be conducted to determine an effective method to measure hair density, to determine the effect of hair density on thresholds associated with the perception of vibration stimuli applied to the head, and to obtain further tactile sensitivity information for the region of the head/scalp. There are numerous studies that measure tactile sensitivity of various parts of the body but there is a deficiency of information regarding sensitivity thresholds for the area of the head/scalp. I identified and proposed the digital microscope and methodology that will be used to measure hair density. In addition, I conducted a pilot test to prepare for the actual experiment by determining the level of displacement to be presented during the first trials of the experiment and created the random, presentation order of treatments. The zippy estimation by sequential testing (ZEST) procedure will be used to find threshold values for each of the conditions, and hair density will be categorized based on a photographic scale. The findings of this study should begin to fill in the gap of information concerning vibration detection thresholds on the head and also aid in the extension of the use of head tactile technology to women.

I wish to acknowledge the mentorship of Dr. Kimberly Myles.

Developing New Materials for Higher Energy Batteries

Magnus, Julianna

The objective for this project was to develop better lithium-ion batteries with increased energy content, but that limit the weight and/or increase the amount of energy carried by the Soldier in the field. After a review of the existing literature, the work focused on developing new electrode materials that either work at an increased voltage over the state of the art (SOA) or have a higher capacity for lithium-ion insertion. In the first case, the team worked on high voltage phosphate cathodes, which operate at 4.8 or 4.1 V (SOA phosphate is 3.4 V). In particular, the team looked for chemical substitutions to improve the battery performance of the 4.8- and 4.1-V phosphate cathodes. In the second case, silicon anodes were studied, because they can accommodate many more lithium atoms than the SOA anode, graphite. To accomplish this work, I learned how to do solid-state chemical reactions; coat electrode material (carbon-binder composites) onto copper (used for anodes) and aluminum (used for cathodes) current collectors; build functioning lithium batteries; and test the charge and discharge properties of these batteries.

I wish to acknowledge the mentorship of Jan Allen.

Radar Scattering Properties of Urban Structures

Mallick, Debjoy D.

Airborne tracking in urban environments is difficult with obstructed lines of sight to the target due to buildings or other structures. A possible solution involves developing an active RF sensor and reflecting energy off of impeding structures to the target and back. Success of this method depends on the scattering properties of the impeding structures. Characterizing the scattering properties of impeding structures requires using active radio frequency (RF) sensors to measure the transmittance and reflectance of walls made from various materials at various angles. The RF signature research facility at Aberdeen Proving Ground, MD, has the necessary equipment for this level of testing with a tower capable of lifting its tri-band inverse synthetic-aperture radar (ISAR) system to achieve lookdown angles from 0° to 65° and a target turntable capable of 360° rotation. Testing will be done at center frequencies of 9, 17, and 34 Ghz on wood siding, brick, concrete block, stucco, and glass. This data will be compared with similar measurements taken with a flat metal plate as a reflecting surface. The resulting two-dimensional (2-D) ISAR imagery, combined with reflectance and transmittance data from testing, should provide insight into the scattering properties of various materials commonly found in impeding structures in urban environments.

I wish to acknowledge the mentorship of Dr. Steven Weiss.

Integration of Scalable Pseudorandom Number Generation (SPRNG) with ARL Molecular Dynamics Code, Core XMD

Malone, Kayla L.

CoreXMD is a large-scale molecular dynamics (MD) software suite developed at the U.S. Army Research Laboratory (ARL). The software is an Message Passing Interface (MPI)-based application using molecular dynamics simulations of a variety of thermodynamic ensembles, while employing a number of robust integration techniques. New capabilities are continuously being planned and implemented by the ARL Multiscale Reactive Modeling Team (MRM) into CoreXMD. However, the current code is limited to system default random number generator (RNG) algorithms. It is desirable for end-users of the software to have access to a variety of uniform RNG algorithms. SPRNG is a set of libraries developed at Florida State University for scalable and portable pseudorandom number generation. It has been developed mindful of the requirement for reliable and statistically sound simulations. SPRNG features a variety of serial and parallel generator algorithms. The ultimate goal of this project is to integrate the SPRNG libraries into the highly parallel CoreXMD code. Furthermore, the quality of the various RNGs within the libraries are assessed and compared. The SPRNG library is integrated with CoreXMD by developing appropriate subroutines and functions necessary to allow user selection of desired generator using FORTRAN 90 modules.

I wish to acknowledge the mentorship of Dr. Betsy Rice (ARL) and Dr. Andrew Scott (Alabama A&M University).

Atomic Layer Deposition of Dielectric on Graphene for High RF Performance of Graphene Transistors

Marr, Timothy C.

Recent graphene-based transistors (GFETs) fabricated at the U.S. Army Research Laboratory (ARL) have realized ~1 GHz cut-off frequency operation. The top gate dielectric stack used on these devices is composed of a silicon dioxide (SiO_2) seed layer and an aluminum oxide (Al_2O_3) layer. The SiO_2 layer on graphene acts as a seed layer for the nucleation of high-dielectric constant (K) Al_2O_3. Decreasing the thickness and increasing the K of the gate dielectric can improve the frequency performance of these GFETs. Based on results by Lee et al., we investigate thermal and plasma-assisted, ozone-based atomic layer deposition (ALD) techniques in order to mitigate the need for the intermediate SiO_2 layer used on recent ARL GFETs. After deposition of Al_2O_3 or hafnium oxide (HfO_2) on graphene using ozone-based ALD, samples are characterized using atomic force microscopy (AFM) to determine conformal coverage of the dielectric. Raman spectroscopy is used to determine process effects on the graphene quality. Electrical characterization is performed on these graphene devices after dielectric deposition to determine capacitance, leakage current, and carrier mobility. GFETs are demonstrated, and the DC and RF frequency performance are evaluated.

I wish to acknowledge the mentorship of Drs. Osama Nayfeh, Madan Dubey, and Steve Kilpatrick.

Performance Assessment of Face Recognition Using Super-resolution

Maschal Jr., Robert A

Image resolution is a major limiting factor in the performance of face recognition algorithms. The recognition rate of an algorithm decreases with the number of pixels in the face. In surveillance situations, where low-resolution video is captured, image sequences can be used in conjunction with super-resolution to produce a higher resolution image. In this paper, we analyze the performance enhancement super-resolution provides by varying the eye-to-eye distance of the subject and the number of frames used in the reconstruction using a gallery and probe sets taken from a video database of moving faces and people.

I wish to acknowledge the mentorship of Dr. Susan Young and Dr. Shouwen Hu.

ZnO Nanobridge-based Senor Platform and Functionalization for Explosive Sensing

Mason, Ashley D.

Nanowire-based sensors present an alternative to thin-films for improved gas sensing because of their inherently high surface-to-volume ratio. Zinc oxide (ZnO) nanowires have a well-developed vapor-phase growth method and ability to be seeded on carbonized photoresist (C-PR). The C-PR also acts as an electrical contact; however, a molybdenum (Mo) layer decreases contact resistance and masks C-PR areas where growth is not desired. The selectivity of the device is refined using chemical functionalization, first applying a parylene A activation layer by chemical vapor deposition (CVD). We present images of the C-PR, Mo, and NW interfaces taken with a microscope and a scanning electron microscope (SEM), as well as X-ray photoelectron spectroscopy (XPS) and profilometry data characterizing the importance of sample temperature, location, and vacuum pressure during parylene A coating. Electrical data will include current-voltage and current-time measurements showing effects of the parylene A coating and the UV response of the devices. Using the functionalization described here, an array of devices could be created using the same process with only the final layer of functionalization (end-node species) changing. The results gleaned from these experiments can aid in the search for a chemical-based sensor array.

I wish to acknowledge the mentorship of Dr. Brett Piekarski.

Metal Nanoparticles Supported on Graphene for Portable Fuel Cells

McClure, Joshua P.

The U.S. Army Soldiers require safe, reliable, and cheap power sources for use with various auxiliary equipments. Proton exchange membrane (PEM)-based direct methanol fuel cells (DMFCs) have been the primary focus for Soldier portable power sources; however, PEMs require expensive noble metal catalysts. The development of alkaline exchange membrane fuel cells (AEMFCs) enables the use of cheaper catalyst materials. The isolation of graphene in 2004 revamped interest for novel carbon supports, making the study of graphene with noble and non-noble metals in both PEMs and AEMFCs exciting and necessary for reducing metal catalyst loadings for next generation catalyst materials. This paper investigates recent demonstrations of various metal catalysts in PEMs and AEMFCs using graphene. The literature suggests that graphene's remarkable tensile strength, thermal conductivity, and surface area makes it a prime candidate as a catalyst support, so it was necessary to reproduce/develop synthesis procedures for making graphene and metal supported graphene. Several methods have been used to characterize graphene including ultraviolet-visible (UV-vis), Raman spectroscopy, Fourier Transform-Infrared (FT-IR), atomic force microscopy (AFM), high-resolution transmission electron microscopy (HRTEM), cyclic voltammetry (CV), rotating disk electrode (RDE), and rotating ring disk electrode (RRDE). These studies are validated using published experimental data and comparison to PEM and AEMFC literature.

I would like to thank Dr. Deryn Chu, Dr. Rongzong Ziang, and Dr. Peter Fedkiw for valuable insight and help with developing new and innovative ideas for improving fuel cell performance.

Sol-Gel Synthesis and Characterization of Rare Earth Doped Materials for Unique Optical Signature Applications

McDonald, Ian

Here we investigate the luminescent properties of two rare earth metals, neodymium (Nd) and ytterbium (Y), having been doped into various host lattices. These host materials have been chosen for their ease of synthesis and lack of fluorescent properties, and include yttrium oxide (Y_2O_3), yttrium aluminum garnet (YAG), and gadolinium gallium garnet (GGG). Once they are co-doped, these rare earth metals allow for a non-radiative energy transfer that produces a material with excitation wavelength of both 355 nm and 906 nm, and an emission wavelength centered around 1000 nm. Effectively, they create a material with the absorbance of Nd and the emission of Y. This energy transfer allows for absorption and emission in the near infrared range—a unique optical signature useful in a myriad of applications. We also investigate their physical, chemical, and optical characteristics as ground powders.

I wish to acknowledge the mentorship of John La Scala.

A 900-MHz PLL Design in a 0.5-µm AMI Process

McKnight, Ken

In this effort, I created a phase looked-loop (PLL) basic type II integer-N frequency synthesizer. The frequency synthesizer was designed for a 900-MHz voltage-controlled oscillator (VCO) frequency given a 9-MHz input and a 450-MHz output frequency with a supply voltage of 3.3 V. The device was fabricated using a 0.5-µm Advanced Metering Infrastructure (AMI) process, a standard digital complementary metal-oxide semiconductor CMOS process with a negative metal oxide semiconductor (NMOS) Ft of 3 Ghz and a nominal supply voltage of 3 V. The type II synthesizer consisted of a digital phase frequency detector with a simplified schematic consisting of two positive edge triggered flip-flops and an "AND" gate, which was used for a reset mode; and a charge pump circuit, which behaved as a directional current switch with a high impedance mode. The VCO was a cross-coupled structure designed for a high slew rate and rail-to-rail output swing. The feedback counter consisted of a generic down-counter preceded by a current mode injection-locked pre-scaler circuit.

I wish to acknowledge the mentorship of John Penn.

Low-cost Object Recognition/Detection and Avoidance

Middleton, Steven

We present a low-cost, object recognition/detection avoidance (ORDA) system that uses image processing algorithms running in parallel on a off-the-shelf digital camera. These algorithms take advantage of an off-the-shelf digital camera's adjustable focal length, field of view (FOV), YUV colors space, edge detection functions, and autofocus features. Autofocus algorithms are also modified to measure color intensity, which increases accuracy. This parameter determines a rough distance from the object and the rough size of the object. The method proposed is comparable to, and considerably cheaper than, a LADAR-based system for navigational use (not imaging use). The algorithms were written in visual C and are being tested using the SRV-1 Blackfin surveyor WIFI robot system. A general outline of the algorithm and the methods used to navigate around and avoid objects is presented.

I wish to acknowledge the mentorship of Keith Aliberti.

Improving Anomaly Detection Using the MATLAB Image-Processing Toolbox

Moultrie, Brandon L.

The Anomaly Detection software is being developed to detect possible threats in the current battlefield environment. A series of sample images were taken containing objects that would be a threat to a Soldier's life if left undetected. The goal of this project is to develop and test software, using the image-processing functions in MATLAB, that may improve detection of anomalies in salient areas of an image. The MATLAB functions under investigation are edge detection, color segmentation, feature detection, and texture analysis.

I wish to acknowledge the mentorship of Dr. Adrienne Raglin.

Molecular Dynamics Study of the Orientation Dependence of Phase Transitions and Deformation Mechanisms in RDX

Munday, Lynn

The concentration of energy and creation of hot spots in crystalline hexahydro-1,3,5-trinitro-1,3,5-s-triazine (RDX) is influenced by localized deformation features. This work presents results from molecular dynamics simulations of RDX using a flexible molecule potential energy function to elucidate the formation of these localized features. Equilibration simulations are used to validate the orthortropic α– and γ-RDX crystal structure and properties to experiment. The competition between cleavage fracture and dislocation nucleation at a crack tip in α-RDX is then evaluated using Rice's continuum formulation. Rice's analysis leads to a new material parameter, the unstable stacking fault energy, which is the maximum energy encountered for sliding on a slip plane from molecular dynamics simulations. This work determines the gamma surface, or stacking energy, on the (010) and (001) slip planes. Maximum saddle points from the gamma surface are compared to the free surface energy to determine the likely nature of deformation on these planes.

I wish to acknowledge the mentorship of Peter Chung.

Release Testing: An Overview

Murray, Colin

This paper focuses on release-testing version 2.23 of the Modular UNIX-based Vulnerability Estimation Suite (MUVES-S2). Release-testing is the process by which a new revision of a software project is tested to ensure that any new, modified, or removed code or features function correctly. The testing involved most of the MUVES-S2 components on several different platforms; the lessons learned and experience gained through this testing helps to improve and maintain the documentation on release-testing. Not only can this information support MUVES-S2 and its future development, but it may possibly give insight into different methods or current pitfalls in the system.

I wish to acknowledge the mentorship of Geoffrey Sauerborn.

Android Applications for Applied Anomaly Detection Project

Nobles, Nicoya D.

The objective of Applied Anomaly Detection project is to assist with training for Soldiers in enhancing situational awareness. The overall goal is to develop full mobile applications for similar software on a downloadable Android application platform. However, the technical approach of this project was to investigate the environment for the Android Platform 2.1 and the functionality needed to support the initial phase of this project. The two main tasks were to incorporate the Android Development suite within the Detection Enclave on the Integrated Distributed Virtual Research Network (IDVRN), and test applications with text and images.

I wish to acknowledge the mentorship of Dr. Adrienne Raglin.

Optical Characterization of Ultraviolet Retro-reflective Patches

Olver, Ian M.

Ultraviolet (UV) retro-reflective patches were researched to test their ability to reflect UV light and transmit visible and infrared light. These patches are small, flexible plastic sheets with many small corner cubes designed to retro-reflect UV light. These patches could be a part of future Soldier uniforms, allowing friendly combatants to be easily identified on the battlefield. Initial reflectivity tests were performed using a Perkin Elmer UV/visible (Vis)/near-infrared (NIR) spectrophotometer, but the UV sensitivity of this device proved to be insufficient due to the non-uniformity of the flexible plastic retro-reflecting corner cubes. Transmission of light through the patch was then tested using a Xenon arc lamp, which generates a broad spectrum of white light, dispersed through an ISA-270M spectrometer. This test proved more useful, since the patch was directly in front of the detector. The point of minimum transmission was found along with the width of the non-transmitting window. The measured data was consistent with the design specification of the manufacturer. A light emitting diode (LED) flashlight with peak emission in the reflectivity window and appropriate UV band-pass filters for detection were identified for a future experiment that will represent how a Soldier might use the patches in the field.

I wish to acknowledge the mentorship of Gregory Garrett.

Characterization of Ceramic Tiles

Papapietro, Elizabeth

One key aspect in the development of ceramic composite armor is the characterization of new candidate ceramic materials. I was given the task of characterizing several different ceramic composite tiles. I collected data on the tiles' physical properties, including density and modulus. I also collected data on the specific tiles' dimensions because dimensional consistency can be used to indicate the uniformity of the raw materials, processing, and machining practices used for making developmental and commercially available ceramic tiles. I also learned how the tile specimens are prepared for ballistic testing using steel frames, aluminum backings, and fiberglass wrapping. The characterization process continues in the ballistic testing of the tile specimens. I was able to observe some of the specimens being shot at the range. The process culminated with my visual inspection of the blasted tiles and recording data on the rubble weights and fracture surfaces. My project involves applying this characterization pathway to new ceramic products and analyzing trends to identify top performing materials.

I wish to acknowledge the mentorship of Todd Jessen.

Low Temperature Inductively Couple Plasma Etching of Mercury Cadmium Telluride Anti-Reflective Structures

Pattison, James W.

Mercury cadmium telluride (MCT) is an important semiconductor for infrared (IR) imaging technologies due to its tunable bandgap, which allows detection of short- to long-wave IR wavelengths. Previously, device structures have been created in this material through wet chemical etching processes. Due to decreasing device dimensions and increasing etch aspect ratios, isotropic wet etching is no longer applicable to defining device structures. Fabrication methods are increasingly turning to high-density plasma processes to create anisotropic structures on the micron scale. Inductively coupled plasma (ICP) etching is an attractive device processing technology for achieving high aspect ratios, small device dimensions, and smooth surface morphologies. Smooth surfaces facilitate further device passivation. Currently fielded MCT thermal imaging devices are sensitive to a single region of the IR spectrum, due in part to attenuation by surface reflection, limiting signal generation. This work reports surface reflection reductions through fabrication of MCT anti-reflective microstructures by ICP etching. The fabrication was accomplished using a new interrupted etching technique with argon plasma at cryogenic temperatures. This process removes any chemical component to gas chemistry (i.e., H_2 or CH_4), reducing surface roughness, while the interrupted cyclic low temperature etching minimizes the ion milling damage through sample cooling.

I wish to acknowledge the mentorship of Madan Dubey.

Multi-Cue Human Detection

Paxton, Christopher J.

Current unmanned ground vehicles lack the Soldier's capability to adequately and quickly identify humans robustly and with sufficient accuracy for Soldier mission needs. There exists a wide array of technologies for the detection of humans using video, infrared, or range data, yet each individual system only works in very specific circumstances. Integration of various such technologies into a single system could greatly increase the effectiveness of computer vision techniques in human detection. The OpenCV computer vision library contains implementations of several useful computer vision algorithms, including the Viola-Jones algorithm and Histogram of Oriented Gradients feature detection, and also contains the tools necessary to implement others. It was used to test the usefulness of combining computer vision algorithms in this manner in a wide variety of circumstances, finding that it could increase detection and could also be used to improve performance by using less computationally costly algorithms to eliminate areas that could not contain humans.

I wish to acknowledge the mentorship of Phillip David.

Fragment Processing and Analysis for the Joint Trauma Analysis and Prevention of Injury in Combat (JTAPIC) Program

Ploskonka, Ann M.

The analysis of fragments removed from Soldiers killed in action (KIA) is vital to understanding the vulnerabilities to threats that they face in-theater, as well as for understanding enemy tactics, techniques, and procedures (TTPs). As part of the Joint Trauma Analysis and Prevention of Injury in Combat (JTAPIC) program, fragments of particular interest are removed during autopsy by the Office of the Armed Forces Medical Examiner (OAFME) and sent to the U.S. Army Research Laboratory's (ARL) Warfighter Survivability Branch (WSB) for analysis. The fragments are processed and analyzed, and these results are entered into the JTAPIC Fragment and Material Database. The processing and analysis data includes fragment photographs, dimensions, weight, density, three-dimensional scans, and elemental analysis results. The JTAPIC fragment analyses enable analysts to determine the identification of the fragment and determine the fragment's origin. This information is used in event recreations, modeling, and simulation. This paper focuses on all phases of the fragment analysis, including receipt of fragments and coordination with the Weapons and Materials Research Directorate (WMRD) for scanning and sterilization. Upon completion of WMRD's efforts, the students processed and analyzed all fragments and entered their results into the database.

I wish to acknowledge the mentorship of Karen Pizzolato and Barbara Wolfe.

Strain Rate Response of Epoxies Under Uniaxial Compression

Pritts, Jr., James E.

Strain rate responses of several epoxy materials were investigated under uniaxial compression at two different rates, 10^{-3}/s and 10^{-1}/s. The cross-linked polymer epoxies were tailored by glass transition and Tg temperatures. True strain rate controlled experiments were conducted using an Instron servo-hydraulic test machine. An exponentially decaying waveform input was generated for each sample based on its gage length. The waveform contained voltage multipliers that facilitated true strain rate control during testing. The effect of annealing on the samples was observed to determine if residual stresses from machining affected the mechanical properties. Each epoxy was compared by plotting the modulus and yield strength as a function of strain rates.

I wish to acknowledge the mentorship of Paul Moy.

Nano-electromechanical Storage Element for Low-Power Complimentary Logic Using PZT Switches

Proie, Robert

Lead zirconate titanate (PZT) microelectromechanical system (MEMS) actuators have been developed for low-power digital logic computation. The concept of mechanical logic has been reported on by several groups previously and a Defense Advanced Research Projects Agency (DARPA)-funded nano-MEMS (NEMS) initiative exists to further this field. This paper introduces a unique six-terminal PZT relay optimized for combinational logic computation and demonstrates a key functional element within this technology, memory. Here, I report on the design and reliable operation of a complete dynamic latch. The latch consumes 0.82 nJ of energy for one read and write cycle. In addition to low power, this technology is directly integrable with existing PZT based radio frequency (RF)-MEMS switch and resonator technologies and is less susceptible to high-energy radiation sources than the metal-oxide semiconductor field-effect transistor (MOSFET) alternative. This relay provides a direct digital computation capability to a platform that previously required a multichip control solution, reducing fabrication complexity and cost.

I wish to acknowledge the mentorship of Tony Ivanov and Ed Viveiros.

Interactions of Quantum Dots and Small Interfering RNA for Therapeutic Applications

Provenza, Danielle

There are many different types of quantum dots (QDs) that can be used for bio-imaging and the tracking of cells. But all of them have one thing in common: they can show the exact path that the cell is taking. QDs also have the ability to be attached to bio molecules or have antibodies attached their surface as a possibility for fighting cancer cells. Cancer cells, however, are deceptive and use ribonucleic acid (RNA) to reproduce the deoxyribonucleic acid (DNA), and the proteins of the unhealthy cells create more abnormal cells, causing the cancer to grow stronger. But there is an interference factor that could be very useful in the RNA. Called small interfering RNA (siRNA, RNAi), this type of RNA has been attracting a lot of attention because of its abilities to stop gene expression or create what is called gene silencing. This work focuses on the interaction and attachment of siRNA (brain cancer gene) to cadmium selenide (CdSe) quantum dots for potential delivery of the siRNA into the cell nucleus. Analysis and characterization of the interactions is performed using ultraviolet-visible (UV-Vis) spectrometry, fluorospectrometry, and atomic force microscopy.

I wish to acknowledge the mentorship of Dr. Shashi P. Karna.

Physical Measurement Fixture Design

Rainey, Thomas R.

The measurement of physical properties of projectiles plays an important role in the characterization and development of advanced weapons systems. Because of this, and the rapid increase of technology, it is necessary to have an efficient method to measure these properties with ease and precision. This paper details the design process of two fixtures needed to measure the center-of-gravity and moment-of-inertia of varying caliber test projectiles. These fixtures were intended to offer a more efficient way to measure these properties on the new machines recently purchased by the U.S. Army Research Laboratory (ARL). A specific goal of the improved fixture design was to allow measurement of these two physical properties on different machines using the same fixture. This creates a significant time savings and error reduction, as they can be used on several measurement machines without removal of the projectile to a separate fixture or adjustment of the projectile position. A modified v-block design with an end-stop at the back is used to accomplish this. This design is able to accommodate the variously spaced bore-riders as well as smooth surfaces on a wide variety of projectiles. Comparisons with prior fixtures are also offered to highlight the effectiveness of the new design.

I wish to acknowledge the mentorship of Jim Garner.

Extraction of Graphene by Exfoliation and Transfer

Raju, Vinay

Graphene is a two-dimensional lattice of carbon atoms that exhibits various unique characteristics. Graphene has many potential future benefits for the American Soldier, including smaller, more efficient electronics. This project explores the process of extracting graphene from two difference sources. One process is mechanical exfoliation, which involves the “Scotch-Tape” method. In this process, graphene is cleaved into films that are one atomic layer thick. The graphene film is then pressed onto silicon wafers. Mechanically exfoliated graphene produces high quality, uniform single-layer graphene. This process generates sporadic flakes which can be observed and measured using different forms of metrology. These forms of metrology include optical microscopy, Raman spectroscopy, and atomic force microscopy, which allow us to observe the quality and thickness of the graphene (single- and bi-layer). The other process that will be used to extract graphene involves transferring the material from nickel-coated templates to an arbitrary substrate. We transfer the films of graphene in a manner which allows the films to preserve their continuity and attach strongly to substrates. This transfer process gives us large-area production of graphene. Both of these processes will allow us to use graphene on any substrate to build novel devices for the Army.

I wish to acknowledge the mentorship of Matthew Chin and Dr. Osama Nayfeh.

Using Kinetic Monte Carlo to Explore Physics of Quantum Dot Growth

Ramsey, James J.

A qualitative Kinetic Monte Carlo model has been developed to simulate Stranski-Krastanov growth of quantum dots on a (001) substrate of tetrahedrally coordinated semiconductor material. It takes into account three different kinds of anisotropy: elastic anisotropy of the substrate, anisotropy in diffusion of isolated particles deposited onto the substrate (or single-particle diffusional anisotropy), and anisotropy in the interactions amongst nearest-neighboring deposited particles. Elastic effects are taken into account through a phenomenological repulsive ring model. Effects of elastic anisotropy appear more pronounced in some experiments than others, with an anisotropic model needed to reproduce the order seen in some results, while an isotropic model better explains the results from other experiments. The single-particle diffusional anisotropy appears to explain the disorder in arrangement of quantum dots that has been seen in several experiments. Anisotropy in interactions among nearest-neighboring particles appears to explain the oblong shapes of quantum dots seen in growth experiments of indium gallium arsenide (InGaAs) dots on GaAs(001), and partially explain the presence of chains of dots, as well.

I wish to acknowledge the mentorship of Dr. Peter Chung.

Topodef Revitalized

Rao, Chirag

The topology-definition (Topodef) tool is a U.S. Army Research Laboratory (ARL) application implemented to initialize the positions, pathways, and signal behaviors of mobile wireless network nodes. It is a useful tool for researchers interested in designing a mobile network scenario with predefined conditions, such as a specific signal propagation loss model, a specific clustering of nodes, etc. The current implementation of Topodef is not designed for smooth accommodation of potential future enhancements, such as three-dimensional network simulation. This application, therefore, requires greater modularization and restructuring to allow for easier maintenance and refurbishment. This paper explains how Topodef could be modified, including how to reorganize the class hierarchy and class content. In addition, the paper describes current efforts being made to improve Topodef, followed by an assessment of what improvements may be considered in the future.

I wish to acknowledge the mentorship of Andrew J. Toth.

Graphical Editing Interface for BRL-CAD Mesh Geometry

Reed, Nicholas W.

The Ballistic Research Laboratory's Computer Aided Design suite (BRL-CAD) is a software platform for modeling and analyzing three-dimensional geometry. Its primary function is to support the modeling and analysis of military targets for use in vulnerability/lethality studies. BRL-CAD provides tools for manipulating meshes of interconnected polygons, since target modelers often have to work with mesh geometry. Mesh geometry can be quite complex, consisting of thousands of faces and vertices, and modelers who work with this kind of geometry are always looking for easier ways to manipulate it. The ultimate goal of my work is to create a comprehensive graphical user interface for editing mesh geometry in BRL-CAD. This effort will make it easier for modelers to use existing tools and will potentially provide them with new ones, allowing them to be more productive.

I wish to acknowledge the mentorship of Edwin Davisson.

Validation of SPLIT-X Model for Predicting Fragment Velocities

Reichenbach, Nathan

To meet the unique needs of the warfighter, it is essential to approach any engineering problem from both an experimental and computational approach. Relative to experimental design, computational design is still in a development stage and, as physics-based models advance, so will our capabilities. WMRD recently acquired SPLIT-X, which analytically models case expansion of simple cylindrical geometries to calculate case velocity, similar to Gurney's Method. A fragmentation model is then superimposed with the analytically calculated velocities. The objectives for this mission are to (1) develop LMB's own methodology for the modeling of more complicated (actual) warhead geometries using currently available physics-based models (such as ALE3D or CTH) and (2) verify that this new methodology and SPLIT-X accurately calculate case velocities when compared to experimental data. Thus far, most of the effort has been dedicated to the initial verification of velocity calculations with ALE3D. This is being accomplished by testing simple cylindrical geometries (for which we have both experimental data and SPLIT-X calculations) using ALE3D. Once the calculations are completed, it is expected that the results will correlate sufficiently with both experimental and SPLIT-X data. This new technology should significantly improve the performance of future warhead designs.

I wish to acknowledge the mentorship of Mr. Richard Summers.

Bio-inspired Navigation Algorithm and Hardware Integration on a Mobile Robot

Reid, Cordell R.; Schneider, Kathryn E.; Helms, Tristan P.

A dual-membrane microelectromechanical system (MEMS) acoustic localization microphone based on the hearing mechanism of the *Ormia Ochracea* parasitic fly is being developed by the U.S. Army Research Laboratory (ARL) as a promising low-power navigation method for small-scale (millimeter to centimeter) robotic platforms. This bio-inspired device should enable autonomous mobile robots to search for the source of a sound, such as sniper fire or a voice, increasing situational awareness. This project focuses on developing and testing an algorithm for eventual use with the MEMS microphone that can enable an autonomous robot to detect a sound source, turn to locate it, and then approach and follow it. Since the microphone is under development, this project uses two Tibbetts 151-01 omnidirectional microphones separated at a scaled distance relative to the two membranes in the MEMS device. The algorithm incorporates the Interaural Time Difference (ITD), Interaural Intensity Difference (IID), and Interaural Phase Difference (IPD) to determine the azimuth angle between the source and the center point between the two microphones. The algorithm then instructs the robot to move and take another measurement to triangulate the location of the sound source. Future work will include adapting the basic algorithm for use with the actual MEMS directional microphone.

We wish to acknowledge the mentorship of Dr. Luke Currano, Mr. Arthur Harrison, and Dr. Alma Wickenden.

Energy-efficient Navigation and Route Planning for Small Autonomous Mobile Robots

Reid, Cordell R.; Schneider, Kathryn E.; Wolff, Eric M.

The operational lifetime of millimeter- to centimeter-scale autonomous mobile robots is severely constrained by their limited battery capacity due to size and load-bearing abilities. We investigate the problem of increasing robot lifespan by strategically planning paths through an environment that minimizes energy use over terrain while simultaneously maximizing the available solar energy that can be harvested by the robot. We make the assumption that the environment is initially unknown and that the robot can only sense a small portion of it, which requires that the robot is able to identify both terrain and energy sources at a distance. Infrared (IR), acoustic, color, and light sensors are investigated to reduce processing power relative to vision-based sensors. We modified the D* Lite graph search algorithm to include high-level control logic that makes planning decisions with respect to power and time constraints. We experimentally validated our algorithm by implementing it on a Surveyor SRV-1 robot and directly measuring power consumption as it navigated in a test environment. Our algorithm showed that increased operational lifetimes are possible by considering terrain and energy sources during planning.

We would like to thank Dr. Brian Morgan and Dr. Alma Wickenden for guidance on this project.

Control of Hexapedal Trajectory Path Tracking

Rice, Joseph B.

Mobile micro-robots (MMRs) have become an increasing popular field of study due to their myriad of applications. More specifically, walking and crawling MMRs have become useful in terms of their high mobility, subtle appearance, and low cost when compare to similar wheeled and tracked platforms. Unfortunately, to date, walking/crawling MMRs use primitive ambulation control. In this paper, we model a 12-degree of freedom (DOF) hexapod in order to better understand the mechanics of walking, six-legged platforms. The research is divided into two sections. In the first, we developed a control scheme for a nonlinear, spherical pendulum model of the hexapod. Adaptive control was also added to the leg to ensure stability regardless of external disturbances. Next, we treated the legs as a decoupled system and focused on the control of the hexapedal trajectory tracking. This decoupling allowed the control scheme of the hexapedal's path to be simplified into a single input, single output (SISO) system.

I wish to acknowledge the mentorship of Christopher Kroninger.

An Approach to Taking Dynamic Range Measurements for Devices with RF Front Ends and Digital Outputs

Ripple, Kelly M.

The purpose of this project is to demonstrate a new approach to taking dynamic range measurements in devices that do not have an intermediate frequency (IF) port. To this end, two measurement setups were devised. The first evaluated the characteristics of a mixer within the receiver of a radio frequency (RF) system. The band-pass filter, demodulator, and low-pass filter elements typically seen in an RF receiver were ignored for the sake of simplicity. Traditionally, RF signals are injected through an analog input port and measured through the analog IF output port. In the proposed approach, an RF directional coupler was added between the incoming RF input signals and the analog input port of the mixer. This enabled measurement of the mixer's output signal through the reflected port of the directional coupler, thereby eliminating the need for an analog IF output port. In radio systems on a chip, the analog IF output port is not available, and using a directional coupler is determined as the only way to measure the spurious free dynamic range of a mixer. Experimental results show that the proposed one-port measurement may serve as an adequate substitute for the traditional two-port measurement in these cases.

I wish to acknowledge the mentorship of Gregory Mitchell.

High Power Multimode Fiber MOPA with SBS Beam Cleanup and Phase Conjugation

Rogers, Steven, D.

Research in the power scaling of lasers is a constantly evolving process. One very promising branch of this research is in the area of high power fiber lasers. Our research of high power fiber lasers contains two main stages. The first stage is the creation of a fiber master oscillator power amplifier (MOPA). The second stage involves restoring the beam quality of the amplified signal through stimulated Brillouin scattering (SBS) by (1) phase conjugation and (2) beam cleanup. The difficulty with power scaling in fibers is that their geometry is conducive to unwanted stimulated Brillouin scattering. However, this same geometry is what gives fibers the potential to be exceptional amplifiers. We intend to show that the use of a large mode area (LMA) fiber amplifier will accomplish sufficient amplification while staying below the SBS threshold. We also intend to show that we can take the amplified multimode output beam from the fiber MOPA and restore it to an amplified single-mode diffraction-limited beam, through prudent selection of both short step index and long graded-index SBS fibers/parameters. We will confirm these parameters through experiment and find the ideal operating conditions that promote SBS.

I wish to acknowledge the mentorship of Dr. Jeffrey White and Dr. John McElhenny.

Semi-automatic Methods for Refining a Domain-specific Terminology Base

Rose, Gabriella

A domain-specific term base is essential not only as a resource for written and oral translation, but also for Natural Language Processing (NLP) applications, text retrieval, document indexing, and other knowledge management tasks. The objective of this investigation was to explore the use of alternative terminology extraction methods to refine and validate an existing military-specific bilingual dictionary. A series of semi-automatic methods was implemented to distill the existing term list by removing redundancies, resolving spelling variations, and separating individual expressions. Once the internal clean-up was completed, we compared two methods drawn from the terminology extraction literature in order to validate terms as military-specific and to propose a candidate list of non-specific terms for exclusion—term frequency calculations and terminology extraction lists. In this investigation, we wanted to find the best procedure to extract domain-specific terms for a low-resource domain; to demonstrate that terminology extraction methods can be used to validate and refine a domain-specific dictionary; and to provide the final, refined dictionary as a term base to support customization of machine translation systems for the military domain.

I wish to acknowledge the mentorship of Melissa Holland.

Design and Characterization of a PiezoMEMS Stator to Drive an Ultrasonic Traveling Wave Motor

Rudy, Ryan

Microelectromechanical systems (MEMS)-based ultrasonic motors provide an enabling technology for the realization of optical sense and transmit chips for distributed sensing applications. The monolithically integrated microscale ultrasonic motor platform represents a core technology that will provide revolutionary improvements in size, weight, speed, torque, and power requirements for precision rotary actuators. The first part in this development is to design and characterize a piezoelectrically driven stator fabricated from lead zirconate titanate (PZT) thin films. Initial devices have been fabricated by the U.S. Army Research Laboratory (ARL) team and will be characterized for performance. Based on these initial results, the stator design and operation will be refined through a combination of analytical and finite element models.

I wish to acknowledge the mentorship of Gabriel Smith and contributions from Dr. Ronald G. Polcawich and Dr. Don Devoe.

Preparation of Organic Samples for Force Detected Spectrometry at 4 K

Rushing, Samantha F.

Our goal is to prepare organic samples for force detected nuclear magnetic resonance (NMR) spectroscopy that will survive the harsh conditions to which they will be subjected. We prepare two types of samples—yeast cells and organic thin films. We prepare yeast cells in ways that address the problems identified with past approaches. We developed protocols to fix the cells and both disperse them on and adhere them to a gold sputter-coated sapphire substrate. The organic thin films will be prepared by spin-coating. Several common organic molecules were studied as possible candidates for organic thin films. Candidate molecules were selected according to the chemical shifts of their protons or C-13 atoms. Performing C-13 NMR spectroscopy, as opposed to H-1 NMR spectroscopy, may be advantageous because C-13 NMR spectrometry yields chemical shift parameters that are both larger in magnitude and can be easily distinguished with the strategic placement of C-13 atoms.

I wish to acknowledge the mentorship of Doran D. Smith.

Electromagnetic Shield Effectiveness of Materials

Russo, John

Electromagnetic (EM) shielding of communications equipment is essential in maintaining the integrity and continuity of information flow. It is increasingly important today as the latest manufacturing processes regularly produce devices that can be more susceptible to damaging EM fields (i.e., lightning). Further, understanding the shielding effectiveness of materials of different frequencies is vital for protecting Government and civilian communications facilities from electromagnetic radiation. In this relativity unique measuring technique, EM shielding materials with a high μ are placed in between two loop antennas. One antenna is used to transmit a range of frequencies (10 kHz to 30MHz) generated by a network analyzer. The second antenna receives the radiated signal and feeds that data back into the network analyzer for comparison. Power level ratios are calculated for a set of commonly used shielding materials. I found commonly used thin mesh materials were not effective when compared to solid sheets of materialized materials. The results of these low frequency measurements allows us to extend the use of these materials to lower frequencies and understand EM shield effectiveness beyond the originally intended frequencies.

I wish to acknowledge the mentorship of Marc Litz.

Simulating the Detachment of Leading Edge Vortices on *Drosophila Melanogaster* using CFD

Sabbatini, Alex

Computational fluid dynamics (CFD) simulations have been used to study various aspects of microscale flapping wings based the *Drosophila sp.*, including the delayed wing rotation at the end of each stroke in quasi-steady hovering flight and its effect on the resulting unsteady aerodynamic forces found throughout the wing; the lift and power requirements for *D. Virilis*; and the specific power (the sum of aerodynamic and inertial power requirements normalized to the fruitfly's muscle mass) compared to values from tethered fruitflies. Another comparison showed strong agreement between the "translational" and rotational wing motions, supporting the use of CFD models in the parametric design process of microscale flapping wings. In this effort, I focused on the detachment of leading edge vortices (LEV). Solving the Navier-Stokes equations in the time-varying coordinates of the flapping wing is challenging computationally but offers the possibility of predicting the behavior of the LEV-shedding phenomenon, to which flapping wings owe a majority of their lift. In addition to aiding the study of the LEV-shedding phenomenon, CFD simulations enable one to quickly assess the effect of wing shaping on vertical lift. I developed preliminary code in MATLAB with these two potential aspects in mind.

I wish to acknowledge the mentorship of Gabriel Smith and Jeffrey S. Pulskamp and contributions from Dr. Ronald G. Polcawich and Imraan Faruque.

Study of Sol-Gel PZT Texture by Varying Annealing Conditions

Sanchez, Luz

Controlling lead zirconate titanate's (PZT) crystallinity and texture should enhance the performance of its ferroelectric and piezoelectric properties. Using lead titanate ($PbTiO_3$) as a seed layer, the degree of orientation in PZT was determined using the Lotgering factor. This research demonstrated an improvement in the 001/100 orientation in PZT from f=0.66 to f=0.96. The aim was to further improve PZT orientation by analyzing the effect of the seed layer as a function of annealing temperature between 600–740 °C at 20 °C intervals using a highly textured (111) platinum (Pt) films (full width at half maximum [FWHM] of <5°). The rapid thermal annealing (RTA) ramp profile (single or multiple dwell temperatures) and ramp speed were also studied, investigating a ramp range from 4 to 200 °C/s. PZT solutions with different Pb excesses were also examined to further refine the Lotgering factor of the PZT. Characterization included x-ray diffraction and the ferroelectric, dielectric, and piezoelectric properties of the PZT thin films and PZT actuators.

I wish to acknowledge the mentorship of Dr. Ronald G. Polcawich and the contributions of Dr. Daniel Potrepka, Dr. Glen Fox, and Richard Piekarz.

Bullet detection and tracking algorithm results

Sandborn, Phillip A.M.

The U.S. Army Research Laboratory (ARL) has investigated electric-field sensor technology as it pertains to projectile detection and localization, and other studies have shown the effectiveness of using electric-field sensors in detection and localization of objects in free-flight. Objects in free-flight become charged due to friction with the air, and different types of electric-field sensors can be used to detect the distortion created by these charged objects. Simple tracking algorithms derived from closed-form solutions for the electric-field can be used when sensor platforms are relatively simple—e.g., an infinite plane or a conducting sphere. More complex sensor platform geometries, such as Soldier uniforms or vehicles, can create significant distortions in the electric-field of a projectile, thus existing closed-form solutions must be adjusted. This paper proposes a new electric-field sensor tracking algorithm and a geometric calibration method. The error in the prediction of the projectile's azimuth (*x*-*y* bearing) has been characterized to be a function of the azimuth and the inclination of the bullet. Currently, the algorithm can detect the azimuth of a projectile's path to within 5° of accuracy. Several simulated results are presented that demonstrate the application and use of the proposed algorithm.

I wish to acknowledge the mentorship of Dave Hull and Steve Vinci.

IR and Visible Image Fusion

Schnelle, Stephen R.

Effective video surveillance is important in many applications, including a force protection surveillance system for U.S. Army installations. Color and infrared (IR) images work well under different circumstances; the problem of using both images through image fusion was explored in this report. The images were originally manually registered, so the use of Shift-Invariant Feature Transform (SIFT) for automatic registration of the sets was examined. However, IR and visible data show very different features, and this proved unsuccessful. The problem of image fusion was explored through many pixel-based algorithms, both spatial domain and pyramid-based implementations. Some decompositions, such as contrast and ratio of low pass pyramids, are designed to increase the contrast, whereas wavelets reduce redundancy and offer good directional selectivity. The Receiver Operating Characteristics (ROCs) of these different image fusion algorithms were evaluated using a background subtraction tracker. Region-based complex wavelet decompositions with a flux tensor tracker could be a promising path to connect pixel and feature level fusion.

I wish to acknowledge the mentorship of Alex Chan.

Interfacial Polymerization of Nylon in Electrohydrodynamic Viscous Fingering

Schott, Andrew T.

Biomimetic vascular systems are being researched for various applications such as self-healing and fluid transport. One method of creating these vascular systems is through a process called viscous fingering combined with an electric potential, known as electrohydrodynamic viscous fingering, to form a branching pattern. The viscosity difference between the matrix material and the injected liquid has a large effect on the branching pattern. Therefore, different viscosities of the matrix are being tested while maintaining the viscosity of the injected liquid. Current research focuses on forming a controlled branch structure in a curable polymer matrix. Obstacles for the curable system include branch breakup and relaxation before the vascular system is cured. Breakup disrupts the continuous flow of liquid through a network, while relaxation may lead to branch swelling which results in the loss of the fine structure. Another issue exists due to the Hele-Shaw conditions in the two-dimensional setup. The branches are thin, leading to fragility and damage upon removal from the cell. This paper focuses on exploring interfacial polymerizing systems, which result in reinforced branches, as well as preventing relaxation. This could lead to stronger and more defined branches.

I wish to acknowledge the mentorship of Kris Behler.

Summer Modeling for GMB

Schulz, Matthew M.

The purpose of this paper is to document the experiences and knowledge I accrued while assigned to the U.S. Army Research Laboratory's (ARL) ground mobile branch (GMB) of the Survivability Lethality Analysis Directorate (SLAD). This Branch is tasked with the role of providing support through the analysis of current and future vehicular systems and has traditionally done so through the use of three-dimensional (3-D) Ballistic Research Laboratory (BRL) Computer Aided Design (CAD) target geometries and MUVES. The results from analyses are used to provide insight that leads to recommendations for vehicle modifications. These modifications will ultimately increase the survivability of a particular system. I have observed the metrology techniques involved with gathering measurements to create highly detailed component and vehicle geometries, produced vehicle renderings for visual representation, and deconstructed existing target models into component subsystems.

I wish to acknowledge the mentorship of Scott Hornung.

Identification of the Phosphoketolase Pathway in *C. acetobutylicum*

Shankar, Jaishri

Clostridium acetobutylicum is involved in fermentation, resulting in the production of organic solvents, specifically acetone, butanol, and ethanol. Once useful in the early 1900s, it has slowly regained prevalence as energy usage has increased and resources have become more difficult to obtain. Xylose is a particularly attractive as a feedstock, as it comprises 30% of cellulosic biomass. *C. acetobutylicum* grows extremely slowly on this substrate, and efforts to increase the speed would be advantageous. Recent studies suggest that an undiscovered pathway for pentose usage exists in the organism. However, the pathway is induced in arabinose, but not in xylose-grown cells. The purpose of this study is to biochemically characterize phosphoketolase, the key enzyme in this pathway, and determine if this metabolic pathway truly exists. If so, we could attempt to engineer a strain of *C. acetobutylicum* that would induce the pathway in the presence of xylose.

I wish to acknowledge the mentorship of Matthew Servinsky.

The Essay vs. Technical Reports

Sheldon, Claire S.

My initial goal coming into the Oak Ridge Institution of Science Education (ORISE) program at the U.S. Army Research Laboratory (ARL) was to gain more editorial experience and exposure to technical/scientific writing. My analytical, organizational, and stylistic skills as an essay writer were challenged when assigned to edit various technical reports, abstracts, journal articles, and Standard Operating Procedures (SOPs). I found the numerous military and scientific acronyms, as well as the overall language, difficult to understand, primarily because my educational background is in English and History. Typically, when editing, I not only correct grammar and punctuation, but also the tone and style of the piece; however, technical reports lack personality so I focused on the technicalities of proper writing and the overall organization of the reports. It was soon evident that my knowledge of the scientific world was extremely limited, hindering my full understanding of the reports. Nevertheless, this challenge emphasized the importance of keeping some of the language, particularly in the introduction and conclusion of the reports, at an elementary level in order for the research to be appreciated by a larger span of audiences.

I wish to acknowledge the mentorship of Pauline Smith.

Corrosion Behavior of Military Grade Tungsten Heavy Alloy in Simulated Physiological Solution

Shindo, Patrick W.

Tungsten heavy alloys (WHA) are used for kinetic energy penetrators and can become embedded in the body as shrapnel, possibly causing cancer. These alloys are made using a liquid phase sintering process forming a two phase composite of pure tungsten particles surrounded by a binder phase of the alloying elements. We investigate the simulated physiological corrosion behavior of seven formations of WHA to find which ions escape in the body. This was done by conducting 7- and 30-day immersion tests in phosphate buffered saline to simulate the human body. The resulting dissolution product is analyzed via inductively coupled plasma optical emission spectrometry (ICP-OES) to determine the concentration of metal ions leached out during testing. Corrosion rates are derived from weighing the samples before and after immersion. X-ray photoelectron spectroscopy (XPS) and scanning electron microscopy (SEM) are performed on the samples before and after immersion to analyze the surface chemistry and observe the loss of the matrix phase. Potentiodynamic testing, following American Society for Testing and Materials (ASTM) standards, is done on specially made binder-only samples to compare corrosion rates. Preliminary results from SEM indicate that the surface appears identical to *in vivo* conditions. XPS also found heavy oxide formation on the alloys containing iron.

I wish to acknowledge the mentorship of Brian E. Schuster, Ph.D, and the help of J. Derek Demaree, Ph.D.

Bio-inspired Sensor Fusion of Low-Power, Low-Resolution Chemical and Audio Sensors for Target Detection

Shuchatowitz, A.; Wolff, E.

Animals use multiple senses, such as sight, sound, and smell, to robustly navigate their environment and identify objects of interest. Using multiple sensor modalities similar to those found in nature presents an attractive model for millimeter- to centimeter-scale autonomous robots. We constructed a low-power, low-resolution chemical detection system using an array of three chemical sensors aligned to form an equilateral triangle. This design creates a two-dimensional Cartesian coordinate system to pinpoint the direction of highest concentration of vapor molecules for gradient tracking towards a source. The sensor system was coupled on a robotic platform that used a relatively low-power, low-resolution array of acoustic microphones to triangulate a sound source. An algorithm compared weighted sensor response and controlled robotic decision making. The chemical and acoustic sensor modalities were tested independently and then together in locating a “prey” analogue emitting a single frequency sound and ethanol vapors. The integration of both the acoustic and chemical sensors enabled the robotic platform to locate a point source more efficiently than using either sensor independently.

We wish to acknowledge the mentorship of Dr. Alma Wickenden.

Evaluation of Diagnostic and Prognostic Techniques for Oil Cooler Bearing

Siegel, David

Improved techniques for detecting and predicting failures on Army helicopters can provide a substantial benefit with regards to reliability, availability, safety, and maintainability. Existing diagnostic systems use vibration signals to monitor the condition of the rotorcraft drive train, including bearing and gear components. The evaluation of advanced diagnostic and prediction methods can be used to determine the feasibility of including those capabilities into future monitoring systems. This research focuses on the oil cooler bearing, a key component on the rotorcraft. Vibration data collected from an oil-cooler bearing test-rig provided by Impact Technologies, LLC, consisted of baseline and run-to-failure data sets in which the data were collected under different loading and speed regimes, and with bearings of different corrosion levels. Many feature extraction methods were applied, including time, frequency domain, and envelope features, among others. A self-organizing-map distance metric was used to quantify the health of the oil-cooler bearing from the baseline behavior in each regime. Regression based methods used the bearing's health value trend to estimate the remaining useful life. The results are promising and could potentially enhance the reliability of Army-fielded systems. Future work could include using a particle filter-based prediction method for nonlinear and non-stationary vibration signals.

I wish to acknowledge the mentorship of Dr. Canh Ly.

Evaluating Strategies to Open Doors via Compliant Methods

Smith, Daniel C.

Despite numerous advances in the field of robotics, robots are astonishingly poor at such simple tasks as opening doors. The objective of this project is to implement and evaluate various strategies for opening doors with a robotic manipulator through computer simulation. A high fidelity physics engine, Open Dynamics Engine, was used to create a model of a seven-degree-of-freedom arm, the Mitsubishi PA10, in C++. Several different scenarios were constructed, each representing different environments that a door might be placed in. These include the orientation and location of the door, as well as different ways that forces might be applied to auto-closure on doors, and the direction in which a door opens. Various strategies for opening and closing doors were then implemented in the simulation. These include strategies where the motion of the arm and door are controlled entirely by the mobile platform, as well as strategies where the dynamics of the door are estimated by the angles on each joint through physical simulation. The robustness of these strategies was then evaluated across the various scenarios.

I wish to acknowledge the mentorship of Mr. Chad Kessens.

Real-time Power-line Analysis Using Live Relative Phase Detection 2-D (LRPD2)

Smith, Darren

Electric power lines generate significant electric fields due to the electric voltages on the lines and significant magnetic fields due to the load currents. In 2009, the U.S. Army Research Laboratory (ARL) analyzed data from experiments to generate relative phasor plots, a new way of displaying multiple dimensions of relevant data for load events and histories. This paper describes a new tool for analyzing load events in real time. Live Relative Phase Detection 2-D (LRPD2) computes and draws phasors in tens of milliseconds, giving users immediate information for automatic event classification. Live display eliminates the weakness of static phasor plots, the difficulty of understanding transient speed. The tool assists with creating field experiments, understanding and developing algorithms, and rapidly scanning huge amounts of data from old experiments. LRPD2 accepts data over the network from a two-channel sound card or saved data from previous field tests. Intermediate and final processed results, such as relative phase, filtered signal, etc., may be viewed as a waveform or history plots, or logged. Playback of saved data supports pause, fast-forward, and seek. Algorithm parameters, such as frequency, harmonic, and many filter options, can be changed on the fly with automatic recalculation of the resulting phasors.

I wish to acknowledge the mentorship of David Hull.

Ground Tactical Vehicles: Target Modeling and Analysis

Smith, Jason M.

The ground mobile branch (GMB) of the U.S. Army Research Laboratory (ARL) Survivability/Lethality Analysis Directorate (SLAD) plays a vital role in protecting the warfighter deployed in theatre. Using target geometry created in Ballistic Research Laboratory (BRL)-computer-aided design (CAD), together with MUVES-S2, an ARL-developed model used for ballistics vulnerability and lethality analysis computer simulations, the GMB analyzes vehicle and crew survivability to ballistic events. These simulations contribute to improvements in soldier and vehicle survivability. My duties included using BRL-CAD software to create geometric representations of vehicles for use in analysis, developing of CAD renderings of current tactical ground vehicles, and creating a database of vehicle sub-systems for efficient future geometry development. This paper documents some of the details of my efforts, some results of my work, and a connection to how the warfighter is ultimately aided.

I wish to acknowledge the mentorship of Scott Hornung.

Lethality Division

Smith, Mukhtar

MATLAB is a computer program that is often viewed as a complex graphing calculator. Within this program users can write programs as well as view data and much more within the MATLAB syntax. I use the program to design, create, and write graphical user interfaces (GUIs). I used MATLAB to attempt to create a GUI that displays and computes four different sin waves from various inputs. I also worked with my team members in performing more hands-on tasks on the installation. For example, I was able to work with the air gun, a long tube that varies in diameter and length. These tubes are used for testing projectiles to see if the technology within the projectile unit can withstand a standard launch. Another recent project was replacing a pressure meter in the breach room and setting up a display unit in the 7-in air gun control room. We had to stream a series of wires from the control room about 300 ft through the raceway in a tunnel to the breach room. We also had to set up the pressure meter, and ensure it was working properly and was zeroed to display accurate readings.

I wish to acknowledge the mentorship of Morris S. Berman.

The Primary User Emulation Attack in Cognitive Radio and Potential Countermeasures

Sorrells, Calynna

Cognitive Radio (CR) is a new paradigm in wireless communications designed to efficiently use the spectrum by dynamically adjusting its operating parameters to access the unused or white spaces of the licensed spectrum. Primary users (PUs) are the licensed users of the spectrum, and secondary users (SUs) are unlicensed users who use CR to access the white spaces of the licensed spectrum. CR is vulnerable to security attacks because the spectrum sensing protocols do not incorporate security measures, and the CR's highly flexible software-based air interface make attacks feasible. The current CR framework assumes that all users are honest and that attackers do not exist in the network. This paper discusses the jamming attack, Primary User Emulation (PUE), and the vulnerabilities of this attack to Denial of Service (DoS). The PUE attack occurs when an attacker emulates PU signal characteristics, and consequently, the SU cannot distinguish between a legitimate PU signal and an emulated PU signal. This work classifies current defense mechanisms for PUE attack and discerns the weaknesses of these mechanisms. This classification will facilitate an enhanced design for defending against a PUE attack.

I wish to acknowledge the mentorship of Lisa Scott.

The Effects of Peel Ply and Surface Abrasion as Effective Surface Preparation on Secondary Surface Bonding

Spears, Jarell

Surface preparation has been shown to allow a composite to have a rougher, more chemically active surface. The use of surface preparation in vacuum-assisted resin transfer molding (VARTM) processing has been shown to decrease resin content, improve mechanical properties, and increase bond strength. The current VARTM process only uses peel-ply on the top surface. However, initial testing has shown that using a peel-ply and/or surface abrasion on the tool surface may be effective methods of surface preparation for secondary bonding. Using the lap-shear test, two surface preparation techniques were compared on S-2 fiberglass and toughened epoxy resin system. Initial findings show that a lack of surface preparation leads to a poor bonding surface. The first technique resulted in an increase in the lap-shear strength of our composites; by comparison, the second technique improved the lap-shear strength of some of the samples, while decreasing it in others. These results give a better understanding about how multiple types of surface preparation affect the bond strength and ultimately adhesion of the composites, as well as produce the best results in secondary bond strength with this particular system.

I wish to acknowledge the mentorship of Jared Gardner and Larry Holmes.

The Effects of Thermal Treatment on Platinum Bottom Electrodes

Spencer, Kara A.

Electronic devices using parallel-plate capacitor designs require robust bottom electrode structures for optimal performance. Platinum (Pt) thin films are a common choice for bottom electrode material due to their chemical inertness and high thermal stability. In this work, we evaluated the effect of thermal and plasma treatments on sapphire substrates and the subsequent properties of sputter-deposited Pt thin-film electrodes. The surface morphology of sapphire and Pt films was analyzed with atomic force microscopy (AFM), and film stress was evaluated using laser reflectivity with Tencor FLX-2320. Four surface treatments on the sapphire substrates were used in this work. The surface roughness, stress measurement, and sheet resistance (using a four-point probe) were used to analyze the surface of each electrode.

I wish to acknowledge the mentorship of Mathew Ivill and Melanie Cole, Clifford Hubbard, Ryan Toonen, Eric Ngo, and S. G. Hirsh for their time and help.

Synthesis of a Biosolar Cell with the Use of Bacteriorhodopsin

Squires, Kyle

Alternate energy sources are becoming a more important aspect of life. Solar energy is a very promising field of alternate energy with many possibilities. In this research, a new type of solar cell will be investigated. This new solar cell uses a retinal protein called bacteriorhodopsin (bR), also known as “purple membrane,” which is from the bacterial cell called *Halobacterium salinarum*. This protein is used as a proton pump, which captures sunlight and then uses the energy from the sunlight to send protons into the cell. This proton gradient is then used as an energy source for the cell. This research attempts to place the bR onto a titanium dioxide (TiO_2) plate. The bR will then pump protons into the TiO_2 sheet, with the sheet acting as the charge-collecting electrode, transporting the energy into the circuit. This research also attempts to solubilize the bR with detergents in order to make it smaller, so it will be able to go into the TiO_2 plate.

I wish to acknowledge the mentorship of Shashi P. Karna.

Catalytic combustion of 1-butanol coupled with heat harvesting device

St. Clair, Jeffrey G.

A combustor paired with a heat harvesting device, such as a thermoelectric device, can use high energy dense liquid fuels while keeping the chemical and electrical processes separate, making such a system an attractive alternative to batteries and fuel cells for portable power applications. A 1-butanol-fed catalytic combustor using a rhodium (Rh)/aluminum oxide (Al_2O_3) catalyst was tested with a heat extractor—in this case, a stainless steel rod with a copper heat sink. The effects of residence time, fuel flow rate, and rod size on reactor/extractor temperatures and energy balance were observed. Fuel-lean equivalence ratio was also studied and was shown to have little effect. Residence time does not have a direct effect; however, it does provide a catalytic stability limit for the fuel flow rate. The difference in the hot and cold side temperatures of the rod is dependent on fuel flow rate and length of the rod. JP-8, which produces higher temperature ranges than butanol, was also tested as a fuel for the catalytic combustor. The results provide important design guidelines for the catalytic combustion of energy dense liquid fuels as an excellent alternative heat source for either direct use or electrical power conversion.

I wish to acknowledge the mentorship of Ivan C. Lee.

Environmentally Friendly Resins Synthesized from Renewable Resources

Stabler, Christopher B.

Vinyl ester and epoxy resins are used extensively in various commercial applications, and are becoming one of the preferred materials in composite production due to their ease of processability and superior performance. One of the major downsides to the use of vinyl ester and epoxy resins is that their production is heavily dependent on current petroleum prices, which can be expensive and volatile. The synthesis of bio-based resins is an area of interest that must be further investigated for continued usage of composite materials. Aromatic ring structures are common in petrol-derived monomers and introduce rigidity to polymeric structures. Nature produces very few aromatic systems that can be easily used for bio-based resin development. Novel synthetic routes that can produce multifunctional aromatic ring systems starting from bio-refined feedstocks would be extremely advantageous and are currently the focus of this research. Multifunctionalized aromatic rings can be easily modified using a variety of moieties, such as methacrylates and epoxies; this allows for a multitude of possible resin systems that can be used in a number of different applications.

I wish to acknowledge the mentorship of John La Scala.

Hardware Integration of Micro Impulse Generators for Remote Memory Disruption of Compromised Network Devices

Staley, Clay S.

Portable network devices carried by the warfighter present an increased risk of compromising sensitive information if a device is lost or captured in theatre. As a means of absolute information security, Micro Impulse Generators (MIGs) can be integrated into the hardware of high-risk network devices to remotely disrupt their memory if a device is confirmed unaccounted for. A MIG device contains a small (<10 mg) amount of nanothermite material, which, upon ignition, can generate a shockwave capable of rendering targeted memory unrecoverable. This work explores the development of a novel MIG device fabricated through microelectromechanical systems (MEMS) processing and loaded with copper oxide aluminum nanothermite material. Ignition behaviors of the MIG device and energetic material housed within are characterized via current and voltage measurements, and the capability of a MIG device to discretely disable the functionality of a targeted memory chip is evaluated.

I wish to acknowledge the mentorship of Christopher Morris.

Project Oriole Test Sensor Design

Stephey, Tyler P.

Rising from the need to test the Proximity component of the Oriole sensor with as few of the consequences of failure as possible, this design project was initiated to create a less expensive model of the sensor body and provide a more controlled helicopter launch method. To this end, the parachute containment chamber was redesigned for better cost efficiency and mechanical simplicity. We eliminated the spring-loaded anchor legs as a means of securing the chamber and replaced them with mason line. Also, to correct the issue of the initial sensor deployment, we designed a launch tube to eliminate the undesirable rotation of the unit before its drogue chute provided stabilization, to allow the sensor to clear the immediate area of the vehicle it is launched from without incident, and to ensure that the static line does not become tangled or cause the parachute to deploy too early. Finally, the static line release device was redesigned to allow for better operation in conjunction with the new launch tube. Some basic testing has been conducted on the parachute containment chamber with good results, but the actual testing for which these units will be used has yet to occur.

I wish to acknowledge the mentorship of Mr. Brian Mary.

Graphene-Based Flexible Hybrid Energy Storage Device

Sweeney, Charles Brandon

More and more, robotic systems are shrinking in size while their power supplies remain large and bulky. One solution to this problem would be to create a power supply which could be incorporated into the structural frame of the robot. With this goal in mind, it has become necessary to develop flexible energy storage devices that will be fused with rigid building materials, such as carbon fiber or Kevlar, to form dual function composites suitable for micro-robotic applications. For this study, graphene based electrode materials are used due to their high surface area to weight ratio, excellent conductive properties, and high degree of flexibility. These electrodes are then fabricated into battery-supercapacitor hybrid devices, and combined with other novel structural materials to create a rigid robotic building material capable of being formed into nearly any shape.

I wish to acknowledge the mentorship of Mark Bundy.

Introduction of Automation for the Production of Bilingual, Parallel-Aligned Text

Tanenbaum, William T.

As the study and application of statistical machine translation (SMT) grows, progress is often circumscribed by a lack of data. The statistical models that govern SMT engines rely on many large bilingual text corpora, each comprised of vast numbers of bilingual text segments. For certain languages, corpora already exist and help to power translation engines. Regrettably, this is not the case for every language the Army is interested in, making the creation or acquisition of such data a priority. To this end, a language expert in Dari and Pashto was hired, who collected, prepared, and ensured the quality of bilingual text. To explore ways to aid the expert, a variety of the steps performed by the expert and necessary to the process were automated. The hypothesis was that automation of selected processes would improve efficiency, measured in terms of both speed of production, and quantity of data produced, even when time to correct automation-caused errors was accounted for. As predicted, the net result of introducing automation was an increase in both the rate at which correct bilingual segments were produced and the total number of correct bilingual segments produced. The implications of these results for improving larger bilingual data creation and acquisition efforts are discussed.

I wish to acknowledge the mentorship of Melissa Holland.

High-speed Video Angle of Attack Measurement Technique

Teal, Cyle S.

The orientation of a projectile with respect to its trajectory, or its total yaw, is an important factor influencing its performance against armored or unarmored (personnel) targets. Yaw behavior is cyclical over range and small-caliber rounds have a very short yaw cycle, which causes the orientation to change rapidly. The Lethal Mechanisms Branch currently uses a series of orthogonal, multiple x-ray images of the projectile in flight, along with software which fits a curve using the aerodynamic properties of the projectile, to predict the value of yaw at target impact. A technique employing high-speed video imaging could provide a cheaper, more efficient, and more easily implemented experimental setup. This report develops data reduction methods to account for the complications of correcting the apparent position from the camera's perspective into accurate three-dimensional records of the projectile's orientation and position. This technique will provide other government agencies the capability to accurately determine the impact conditions without the expense and NRC-licensing required for radiographic equipment.

I wish to acknowledge the mentorship of Tyler Ehlers.

Correlation of Alkaline Membrane Fuel Cell Performance to Electrode Structure

Thornberry, Courtney

Developing reliable power sources with high energy density (i.e., fuel cells) for various applications is a focus, particularly for the U.S. Army, where Soldiers depend on readily available energy for effectively using important technologies. Current fuel cell development work is based on using the proton exchange membrane (PEM); however, this type of fuel cell technology has drawbacks, including the requirement of expensive noble metal catalysts and slow electrode kinetics. The alkaline anion exchange membrane (AAEM) fuel cell is a promising alternative that has shown good kinetics and allows the use of non-noble catalysts, but it has issues with ion conduction. These issues can be resolved by using ionomers within the catalyst layers (CL) of the fuel cell electrodes, since ionomers provide the needed hydroxyl ionic conductivity within the CL. However, an excessive amount of ionomer shrinks the open space needed for the reactant and product transport, adversely affecting performance. This project seeks to experimentally determine how different types and amounts of ionomers affect AAEM performance, as well as conduct fuel cell characterization tests to determine the electrode properties. Using scanning electron microscopy (SEM), it is hoped that a correlation can be made from the electrode structure and electrode properties to the fuel cell performance.

I wish to acknowledge the mentorship of Dr. Xiaoming Ren and Dr. Deryn Chu.

Design, Construction, and Maintenance of an Automated Cuttlefish Ecosystem

Tom-Wigfield, Noelle

Cephalopods, such as cuttlefish, octopuses, and squids, possess skin with dynamic adaptable appearances unique to the animal kingdom. Dramatic changes to their appearance such as changes in skin pattern, color, and texture are enabled by a sequence of thin layers that are soft and stretchable. The U.S. Army Research Laboratory (ARL) is developing a new research program on the engineering properties and behaviors of cephalopods. To facilitate further study and observation of cephalopod coloration and display capabilities, an aquarium was designed and constructed to house live cuttlefish and octopus in the laboratory environment. The aquarium is a closed system that cleans and cycles water throughout the environment from a display tank, to a filtration system, to a storage tank, and back to the display tank to continue the cycle.

I wish to acknowledge the mentorship of Keith Kirkwood and Keran Lu.

User-based Software Tool for S-parameter Conversion and Manipulation

Trocchia, Scott M.

S-parameters fully characterize the linear behavior of an arbitrary number of ports. We aim to characterize various field-effect transistors (FET), each having a certain gate width and geometry, from their S-parameters. We extract the data from the vector network analyzer in real-time and perform a series of calculations and conversions on the initial S-parameters. Using a software tool written in C++ that interfaces with the vector network analyzer (VNA), the corresponding computer monitor, and two direct current (DC) power supplies, the user can collect relevant real-time statistics about a device under test (DUT). The software includes a number of user-input interfaces paired with appropriate graph canvases. Its main functionalities include: conversion of S-parameters to H-parameters, selection of H21 in an effort to calculate the frequency (f_t) at which the transistor exhibits unity current gain, a family of current-voltage (I-V) plots of the DUT, and calculations and plots of transconductance (gm). Future work will include measuring a variety of devices and allowing the software tool to collect statistics on them.

I wish to acknowledge the mentorship of Dr. Tony Ivanov and Robert Proie.

Radio Source Following Behavior Development for Robots

Twigg, J.; Calderone, D.

Many communication and navigation challenges in autonomous robotics involve maintaining a strong radio connection during missions. In order to maintain communication, robots need to actively seek sources of radio signals to maintain these connections. We integrate a maximum likelihood estimate (MLE) equation developed by Yu and Sadler of the U.S. Army Research Laboratory's (ARL) into Willow Garage's Robot Operating System (ROS) to develop a behavior for following a radio source. This enhanced framework is used to create a simulation environment to guide the development of a radio-source tracking robot behavior. Experimental simulations initially consider one robot following a radio source in an open environment with simulated multipath induced fading of the radio signal. After this simulation is developed, it will be further integrated into the ROS environment to allow detailed visualization of the simulation. This research provides a new framework for complex simulations that allows for the addition of multiple vehicles, boundary awareness, and realistic communication.

We wish to acknowledge the mentorship of Dr. Brian Sadler, Dr. Paul Yu, Dr. Ethan Stump, and Dr. Alma Wickenden.

Modification of Mechanical Properties and Adhesion behavior in Cuben Fiber Mats Using Atmospheric Plasma Treatments

Ucol, Justin M.

Cuben Fiber™ is a fiber-reinforced, Mylar composite fabric currently being considered for use in unmanned aerial and ground vehicles. These applications require a combination of high strength, light weight, and impermeability of lighter-than-air gasses, such as helium (He). These fiber mats are typically chemically inert, which makes it difficult to adhesively bond them for use in inflatable structures. An atmospheric plasma system was used to modify the surface of the fiber mats to improve the adhesive properties of the material without degrading the bulk mechanical integrity. Tensile testing on Cuben Fiber mats was conducted on unmodified specimens, as well as material exposed to a He-oxygen (O) atmospheric plasma discharge. Additionally, T-Peel testing was conducted on untreated and plasma treated Cube Fiber mats using both a urethane-based adhesive and a two-part epoxy. Results indicate a large improvement in bond strength for both the urethane and epoxy adhesives due to plasma exposure, without a significant drop in bulk mechanical strength.

I wish to acknowledge the mentorship of Andres Bujanda.

Determination of Truncated Peptide MRE Binding to Protective Antigen Protein Using Enzyme-Linked Immunosorbent Assay (ELISA)

Val-Addo, Irene

The *Bacillus anthracis* bacteria has the potential to produce the edema and lethal toxins by combining edema factor or lethal factor proteins respectively with the protecting antigen (PA) protein. Since PA is common to the functionality of both toxins, it can be used as a detection method for the proteins that cause anthrax infections. Because antibody-antigen detection methods are time consuming and require specific conditions for testing, alternative methods such as peptide-antigen detection methods are alternatively being considered. Enzyme linked immunosorbent assay is a commonly used method to test for binding affinity of proteins and enzymes and employs the use of visually readable signals of substrate-enzyme reactions. Binding affinity is quantified based on the dissociation constant (K_D) of a peptide-antigen or antibody-antigen complex with low K_D values representing high affinity. A fluorgenic substrate was reacted against a 15-amino acid peptide bound to a PA-enzyme conjugate using the ELISA method. The determined K_D for the peptide was in the range of 680–728 nM, while the binding antibody specific to PA was in range of approximately 3–5 nM. Truncated segments of the full length peptide will be tested to determine a sequence with the highest binding affinity to PA, providing a more efficient alternative for field use.

I wish to acknowledge the mentorship of Dr. Joshua Kogot.

High Rate Injury Biomechanics of Lower Extremities and Application to Protection Design

Vogel, Edward W

Underbelly blasts to vehicles from improvised explosives cause severe injuries to the lower extremities, including bone fracture, ligament tear, or muscle rupture. While these injuries may seem well-defined, the process of injury and the effects of the vehicle system design to protection are still unclear. Developing an understanding of the high rate injury biomechanics associated with blast-induced loading to lower extremities is critical in our support to the Soldier, as well as a rich area of scientific study. This paper discusses efforts focused on developing a finite element model of lower extremities undergoing high rate blast-induced deformation leading to injury. The lower extremity model, including all major leg bones, ligaments, and hips, is developed using a suite of numerical tools. This process involves conversion of medical image data to volume finite elements, a challenging task due to complex anatomical geometry. Simulations of blast events were achieved using the highly parallelized computational tools from Sandia National Laboratory. Significant results were seen in the mechanical responses by the bones and ligaments. Having the ability to model these injuries sustained in such an event could greatly enhance treatments and inspire protective measures.

I would like to recognize the assistance of the entire Computational Injury Biomechanics Laboratory, especially my mentor Reuben Kraft.

Synthesis and Characterization of DNA-Graphitic Nanomaterial Hybrid Structures

Wachsman, Alex

Graphitic nanomaterials, especially carbon nanotubes (CNTs) and graphene, have drawn considerable interest due to their unique properties. Structured as a single layer sheet of hexagonally bound carbon atoms, graphene has been shown to be both mechanically strong and ballistically conductive. Nanotubes consist of rolled sheets of graphene, and exhibit a great variety of electrical and structural variability. Understanding potential interactions between these nanomaterials and biomolecules, including single and double stranded deoxyribonucleic acid (ss and dsDNA), which is the focus of this research, could provide useful information for a number of applications. High-pressure carbon monoxide (HiPCO) grown single-walled CNTs were placed in a 1 mg/mL aqueous suspension and added to a 1 mg/mL solution of 30 base pair long ssDNA in acetate buffer. The mixture was sonicated and incubated at ~10 ºC, and a portion was diluted 10 times. Visual inspection showed that the hydrophobic CNTs had been highly dispersed. Analysis with atomic force microscopy revealed highly separated tube bundles. Inspection of the topographic profile showed a periodic variation in height consistent with ssDNA wrapping.

I wish to acknowledge the mentorship of Shashi Karna.

A 5-W Gallium Nitride Class F Power Amplifier Operating at 2.8 GHz

Waiyaki, Caroline

A key component of microwave telecommunication systems is the power amplifier (PA). A communication system's link performance, power budget, and thermal design are typically driven by the PA's linearity, output power, and efficiency. These design parameters are the key to ensuring an efficient system, because the PA is the most power-consuming circuit in a communication system. This paper presents a 2.8-GHz, 5-W highly efficient PA based on a wide bandgap gallium nitride (GaN) high electron mobility transistor (HEMT) device (CGH40010F from CREE) design that was presented at the 2010 International Microwave Symposium (IMS) High Efficiency Power Amplifier Student Design Competition. The competition, sponsored by the IEEE Microwave Theory and Technique Society (MTT-s), was aimed at getting students involved in this research area. The PA design achieved the competition goal of output power greater than 5 W and the measured power added efficiency (PAE) of 61% PAE at 2.8 GHz

I wish to acknowledge the mentorship of Ed Viveiros.

Crew Incapacitation Report for SOCOM Oshkosh M-ATV Event 1 (29 June 2010)

Weaver, Kate

One objective of Live-fire Vulnerability Tests (LFVTs) is to assess the effects of the threat on the crew. The U.S. Army Research Laboratory's (ARL) Survivability/Lethality Analysis Directorate (SLAD) is responsible for conducting these crew casualty assessments for all ground vehicles subjected to LFVT. This paper documents one such assessment that I conducted during my time in ARL/SLAD. The objective of the LFVT of the Special Operations Command (SOCOM) variant of the Mine Resistant Ambush Protected All Terrain Vehicle (M-ATV) is to determine the effect of additions/modifications of the SOCOM variant of the M-ATV on crew protection from specified blast mines and improvised explosive device (IED) threats. The primary purpose of the test series for the SOCOM variant is to evaluate the potential force protection and crew survivability effects of the SOCOM modifications. A System Level (SL) test was conducted at Aberdeen Proving Ground (APG), MD, on 29 June 2010. ARL/SLAD provided damage assessment support and analysis for the test. The purpose of this paper is to present the crew/personnel incapacitation/injury assessment results of the LFVT for the SOCOM M-ATV.

I wish to acknowledge the mentorship of Gregory Dietrich.

Mechanical Characterization of M855 5.56 mm Ammunition for Manufacturing Optimization

Weerasooriya, Tishan

Recently, the U.S. Army fielded redesigned 5.56-mm ammunition to be used in the M16 rifle. Due to the high rate of production and new design, several inconsistencies in fabrication have been observed—specifically the gap distance between the penetrator tip and the jacket. Samples of M855 rounds with different gap sizes were pulled from the manufacturing facility and machined down to be tested in compression and tension; this was done to understand the forces required to fully insert the penetrator tip into the jacket without deforming the jacket, and the forces required to remove the penetrator from the jacket. Digital image correlation was used to isolate the displacement and load values at which this deformation initiated as a function of starting gap size.

I wish to acknowledge the mentorship of Andres Bujanda.

Influence of Strain on Semipolar III-Nitrides

Wienecke, Steven

This paper analyzes the effects of strain on thin-film (11-22) indium gallium nitride (InGaN) and (20-21) aluminum gallium nitride (AlGaN) samples grown on GaN substrates with various thicknesses via polarized photoluminescence (PL) at room temperature. Measurements were made perpendicular and parallel to the projected *c*-axis of each sample. The difference in peak PL energy of the perpendicular polarization relative to the parallel orientation was examined for both samples. As the InGaN samples became thicker, and fractional relaxation set in, the difference in peak energy increased for perpendicular polarization relative to parallel polarization. This increase is due to the relaxation of the biaxial strain and the development of purely uniaxial strain. This uniaxial strain changes the splitting between the valence bands and, as each are polarized differently, the topmost valence band begins to dominate the overall PL of the sample. The exact opposite was witnessed in the AlGaN samples due to the tensile strain rather than the compressive strain seen in InGaN. Finally, the results were compared to calculations obtained through k·p theory.

I wish to acknowledge the mentorship of Grace Metcalfe

Comparing Cold Spray and Kinetic Metallization Using Nickel Coatings

Wienhold, Erik N.

This work compares two particle consolidation processes: cold spray and kinetic metallization. Both processes rely on high velocity gas flow in order to accelerate particles towards a substrate. Upon impingement, the particles deform and a coating is built up from subsequent impacts. Cold spray generally has supersonic particle velocities, whereas kinetic metallization uses subsonic particle velocities. Both methods will be operated at the parameters recommended by their manufacturers. For this project, the kinetic metallization system will be mounted to a CNC table, which will be controlled by computer-based software. The coatings created by the two different processes will be compared using three categories: deposition efficiency, microstructure, and bond strength. The deposition efficiency will be calculated by comparing the mass of the powder before spraying and the mass of the coating. The microstructure will be analyzed by polishing and etching samples and then using microscopy to determine the samples' porosity. The bond strength will be determined by spraying a thin coating on nickel bond bars and then using an Instron machine to test the adhesion of the coating to the bond bar.

I wish to acknowledge the mentorship of Matthew Trexler.

Highly Oriented Stontium Titanate Thin Films by Chemical Solution Deposition

Weiss, Claire V.

Strontium titanate ($SrTiO_3$ or STO) is a promising perovskite material due to its large and non-linear dielectric response and low loss at low temperatures. Epitaxial, or highly oriented, thin films of complex oxides, such as STO, have been shown to have significantly enhanced dielectric properties at room temperature compared to their randomly oriented polycrystalline counterparts. Although STO has been grown epitaxially, the epitaxial films are either grown on substrate materials that are not integrated circuit (IC) compatible or must be grown by high-vacuum deposition routes, such as molecular beam epitaxy (MBE). If high quality oriented STO thin films could be deposited on IC compatible Si using a non-vacuum deposition method, the dielectric response at room temperature could be improved, while the production costs could be minimized. We investigate the deposition of oriented STO thin films on Si by a simple chemical solution deposition, as well as the associated microstructure and dielectric response of the thin films. We use spin-coating and metallo-organic solution deposition (MOSD), which can produce highly uniform, stoichiometric thin films with the opportunity for scale-up. The films are then characterized using x-ray diffraction (XRD), field emission scanning electron microscopy (FESEM), transmission electron microscopy (TEM), and dielectric measurements.

I wish to acknowledge the mentorship of Melanie Cole.

Design and Construction of a Switched Reluctance Motor

Wenger, Kevin

Switched Reluctance Motors (SRMs) are a relative new type of motor technology that require a complex timing scheme for smooth operation. The design of the controller and the motor often go hand in hand and are packaged together as a final product. This paper outlines the design and construction of both a SRM and its controller.

I wish to acknowledge the mentorship of Drew Wilkerson.

The Effect of Fatty Acid and Ester Cap Branching on Heat of Combustion, Melting Point, and Viscosity on JP-8 Replacements from Renewable Sources

Wexler, Robert B.

The military currently uses JP-8, a product of oil refining, to fuel its vehicles. However, its environmentally unfriendly emissions, rising price, and eminent exhaustion confirm the need for cheap, renewable, and alternative fuel sources that fit strict JP-8 specifications. One possible replacement for JP-8, which is already used commercially, is biodiesel derived from the transesterification of triglycerides from readily available plant oils. The core of this study was to determine the effect of fatty acid branching, ester cap size, and ester cap branching on melting point, heat of combustion, and viscosity. We found was that FA and ester cap branching both had negligible effects on the key fuel properties of this experiment. However, the size of the ester cap, changing it from a typical methyl ester to n-propyl or isopropyl ester, significantly decreased both the melting temperature and the viscosity and only very slightly lowered the heat of combustion. To date, no single fatty acid ester meets all of the requirements to be a standalone replacement for JP-8.

I wish to acknowledge the mentorship of Felicia Levine and Dr. John La Scala.

Influence of Genetic Variability on Individual Differences in Cognition and Personality

Whitaker, Keith W.

As the quantity and quality of intelligent systems in combat increases, there is an increased demand for optimized Soldier performance on cognitive tasks. It is vital that the U.S. Army Research Laboratory (ARL) understands the biological basis of individual differences among Soldiers in order to identify tasks that for which customizable materiel should be developed to offset training demands. We attempted to replicate a number of gene-behavior relationships from the published literature in order to understand the importance of genetic studies for the U.S. Army Materiel Command (AMC). The existing literature, however, is largely inconsistent due in part to the extreme pace of intellectual advancement in areas related to molecular neurobiology. We genotyped 97 individuals for nucleotide polymorphisms (related to SERT, MAO-A, COMT, DAT1, and DRD4) and obtained blood plasma concentrations of serotonin and tryptophan for 32 of these subjects. The subjects performed a number of tests of personality and cognitive performance. We failed to replicate many relationships, including: any link between SERT and Post-Traumatic Stress Disorder (PTSD) or anxiety; any link between MAO-A and impulsivity; DAT1 and any measure of personality or cognitive performance. We showed that SERT and MAO-A genotypes do not predict serotonin levels, but serotonin levels do correlate with several characteristics.

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Automatic Determination of Gross and Subpixel Translational Shifts for Moving Objects in Images for Superresolution

Won, Stephen M.

The U.S. Army depends on reliable surveillance to ensure accurate knowledge of a situation. Imaging instruments sometimes cannot produce high-resolution images due to the circumstances of the operation. Superresolution compensates for this drawback by using the subpixel shifts in multiple images. Correlation is one of the methods to estimate translational shift, but it needs the region of motion to be defined by the analyst. This paper studies the automatic determination of the location and quantity of motion in a set of images. The initial evaluation of correlation, along with a feature correspondence and two optical flow methods, reveals that correlation is suited to only subpixel shift estimation for well-defined images. For gross-shift estimation, feature correspondence yields more accurate results for well-defined images. For images that contain moving objects that are not well-defined from the background, any optical flow method would provide the best results, but correlation may be used instead depending on the application. To automatically identify the area of motion, flux tensor segmentation generally gave the best boundary of moving objects. Studies were validated with simulations in MATLAB and comparisons to ground truths and reference images.

I wish to acknowledge the mentorship of Dr. Susan Young. Dr. Kannappan Palaniappan and Dr. Guna Seetharaman for the demonstration of flux tensors as a method of image segmentation, and Dr. Shuowen Hu for producing the superresolved images given the translation data.

Initial Validation Study of the Human-Robot Interaction Workload Measurement Tool (HRI-WM)

Yagoda, Rosemarie E.

The exchanges between robots and human operators are mediated through an interface, an interaction that has a direct impact on the workload associated with a particular task. Effective workload measurement strategies are needed to ensure optimal human-robot interaction. The human-robot interaction workload measurement (HRI-WM) tool was developed to meet this goal, and we used it in an experiment to assess how communication style and the presence or absence of a second task (e.g., math problems) affects performance. Overall, the addition of a secondary task, regardless of the communication style, increased the HRI-WM task attribute workload ratings; whereas, the system and context attribute ratings remained consistent throughout all conditions due to lack of variability. In turn, the variation in communication style was clearly identified in the team process workload ratings. In summary, the HRI-WM provided a comprehensive account of the workload associated with human robot systems.

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Skeleton Continuity as a Means of Assessing Fiber Tract Continuity in Diffusion-Weighted Imaging

Yu, Alfred B.

Diffusion-weighted magnetic resonance imaging (MRI) is used to estimate the diffusivity of water in the cells of the brain. Further processing of diffusion-weighted images, such as diffusion tensor imaging (DTI) and diffusion spectrum imaging (DSI), can provide a per-voxel estimate of the direction of water diffusion within distinct voxels. Tractography is an analysis that uses this information to reconstruct the white matter fiber tracts connecting gray matter regions, and is useful as a means of identifying individual differences in brain structure. A new metric, skeleton continuity, is proposed as a voxel-wise measure of the continuity within the major white matter tracts in the brain. This metric can be taken to represent the likelihood that a tract that passes through a voxel. This metric can be used to guide tractographic approaches as a means of pre-specifying areas of uncertainty (as would be expected in areas containing crossing fiber tracts). The voxel-wise nature of the metric is particularly amenable to traditional statistical approaches to hypothesis testing, such as general linear models. Skeleton continuity can be used as a summary statistic to capture the location and extent of individual differences in brain structure.

I wish to acknowledge the mentorship of Dr. Jean Vettel and the support of Drs. Ellen Haas and Kaleb McDowell.

Graphene-Based Transparent Conductive Electrodes

Zabinski, Patrick

Graphene, a single-atom sheet of carbon atoms occupying the vertices of interconnected hexagons, possesses extremely high electrical and thermal conductivities, mechanical strength, and chemical and physical stability. In order to explore potential Army-relevant applications, including flexible transparent electrodes, and nanoscale energy-harvesting platforms, methods must be developed to create highly conductive thin graphene films. The goal of this research is to deposit and investigate electrical and mechanical properties of transparent graphene thin films.

In the present work, spin-coating and Langmuir-Blodgett techniques were used to deposit thin graphene films. Films deposited by spin coating were subsequently reduced in a 1mg/ml L-ascorbic acid solution to maximize conductivity. Clumping and a lack of density indicated a lack of polar groups on the graphene surface, inhibiting adherence to the substrate. Work is underway to modify the graphene structure to facilitate maximal binding to a polar surface. Langmuir-Blodgett monolayer film deposition also requires precise control of graphene surface functional groups to facilitate stability at the air-water interface. Graphene samples were prepared and sonicated in varying solvents, demonstrating the lack of solubility in organic solvents, and short-term solubility in water. Graphene treated with L-ascorbic acid displayed strong-hydrophobicity and preferentially dissolved in hexane out of water.

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The Effects of Peel-ply on Secondary Surface Bonding

Zipparo, Steven

Surface preparation has been shown to allow a composite to have a rougher, more chemically active surface. Initial testing has shown that using a peel-ply on the tool surface may be an effective method of surface preparation for secondary bonding. Various peel-plies were selected for testing based on their different material construction, weave patterns, and release coatings. By testing different peel-ply samples, it was discovered that the weave resolution affects the resin content, surface texture, and bond strength. Initial findings show that a lack of surface preparation leads to a poor bonding surface. Two architecturally similar peel-plies produced vastly different results. Grit blasting improved the lap-shear strength of some of the samples, while decreasing it in others. These results give us a better understanding of how peel-plies work, the advantages of using a peel-ply on the tool surface, and what qualities and properties a peel-ply should have to produce the best results in secondary bond strength with this particular system.

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